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TECHNICAL REPORT
68-40-ES

A GENERAL NOMOGRAPH FOR NORMAL AND SKEWED FREQUENCY DISTRIBUTIONS: CLIMATOLOGICAL AND OTHER APPLICATIONS

by

EARL E. LACKEY
Earth Sciences Laboratory

July 1967

Project Reference:
1T025001A129

Series: ES-26

U.S. Army Materiel Command
U.S. ARMY NATICK LABORATORIES
Natick, Massachusetts

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FOREWORD

This report is the last in a series of studies by Dr. Earl Lackey, formerly climatologist in the Earth Sciences Laboratory, on methods of predicting climatic probabilities from incomplete data. In this study, a method is developed which portrays effectively the behavior of temperature distributions under a wide variety of climatic conditions. This enables one to make an effective comparison of these climatological variations and also introduces a simple way of extrapolating small amounts of data to what might result if larger amounts were available, by putting all distributions on a comparative basis.

The approach used in this study is somewhat unconventional from the point of view of standard statistical procedures, but because it does throw light upon the behavior of climatological distributions it is presented here for consideration by other investigators in this field.

L. W. TRUEBLOOD
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Earth Sciences Laboratory

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Commanding

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ABSTRACT

Extended experience in the construction and use of several different predictive nomographs covering a wide range of frequency distributions of various types of weather and other phenomena, suggested the probability that a universal series of patterns of frequency distributions might permeate the whole of nature. This study is based in part on the several nomographic patterns developed in previous studies. It assumes that all of the frequency distributions we are likely to encounter in practical climatology, whether symmetrical or asymmetrical (skewed), may be fairly well approximated by a family of cumulative frequency curves, provided they are plotted on such a scale that 100 units represents the whole range of observational experience in each.

The predictive patterns in the General Nomograph and its associated table depend for their operation on the numerical position of the mean (average) between the two extremes (maximum and minimum) in the frequency distribution, when the three related measures are reduced to a 100-unit scale. The means of frequency distributions having various degrees of skewness lie along a diagonal line from the lower left to the upper right of the basic section of the nomograph. Other lines (curved) trace the values of other percentile or fractional parts of the various distributions. The construction, use and reliability of this nomograph and its associated table are given in this report.

Similar predictive patterns in an Alternative Nomograph and its associated table are identified by the numerical position of: (1) the mean maximum between the absolute maximum and the mean minimum, or (2) the mean minimum between the absolute minimum and the mean maximum, depending on which extreme is being explored. A 100-unit scale based on the above values is used in each case. The Alternative Nomograph thus illustrates the possibility of using parametric data other than means and extremes as the basis for a nomograph, if that should be necessary, or should prove to be a better basis for frequency prediction.

The essential summarized data for use with either nomograph may be secured from printed publications or from isothermal maps. How each source of summarized data may be used, for retrieval or predictive purposes, is shown and the results are verified by comparison with recorded data in the same vicinity.

A GENERAL NOMOGRAPH FOR NORMAL AND SKEWED FREQUENCY DISTRIBUTIONS:

CLIMATOLOGICAL AND OTHER APPLICATIONS

Purpose and scope

This study offers a method whereby the detailed climatic record may be retrieved in part by use of a nomographic device in which summarized data may be used effectively to reconstruct the patterns of weather and climatic phenomena inherent in the record. The mean and the extreme values which are available in summarized climatic records are interrelated in such a way that it is possible to discover from them the detailed frequencies of particular climatic values in the past.

The operation of the nomographic method presented here depends largely on the asymmetrical or skewed position of the mean of any given climatic frequency distribution as a measure of central tendency between the extreme maximum and extreme minimum in a frequency distribution. In using the method, those measures are arranged in a numerical sequence and converted to a 100-unit scale, the extremes of which are the extremes of the distribution, 0 to 100, respectively.* A commendable feature of the method is its adaptability to either manual or machine processing.

*It is also possible to base the 100-unit scale on values other than the extremes of the distribution, and use the means of the extremes as measures of skewness. See Part V.

PART I. PRELIMINARY CONSIDERATIONS

1. Some previously published studies

A nomographic method for determining hourly distribution of temperature was published by Spreen in 1956 using the monthly mean, the mean maximum and the mean minimum as the essential measures (11).

Another nomographic method for predicting hourly distribution of temperature was proposed by Lackey in 1960, based on 10-year records, featuring monthly means and the associated 10-year extremes (5). A companion study appeared in 1964 for assessing the percentage frequency and probable amounts of one-day rainfall, based on the mean monthly precipitation, and the maximum one-day rainfall, in a series of 10-year records (7). Other studies by Lackey dealt with maximum temperature probabilities (8) and minimum temperature probabilities (6, 9).

A whole series of U.S. Weather Bureau Technical Papers is devoted to the analysis of weather and climatic data. Several of these deal with frequency and areal distribution of temperature (12). Areal and frequency distribution of precipitation is covered for most of the United States in Technical Report No. 15 with its more than twenty-five separate parts - mostly by states.

A number of in-house U.S. Army Handbooks (10) deal with the analysis of climate at specific locations in different parts of the world. Each of these presents in graphical and tabular form, the frequency and level of temperature distribution to be expected for each month of the year. Some data from three of these Handbooks are discussed in III, 2, this report.

2. Integrating Features

a. Nature and purpose of the 100-unit scale

Very early in our study of arithmetic we learned that in order to compare or combine two or more fractional values, it was necessary to reduce or change them to a common denominator. For example, $1/2 + 1/5 + 1/10 = 5/10 + 2/10 + 1/10 = 8/10$. Later, we discovered we could change all fractional values to a universal denominator - the decimal fraction. Moreover, we learned also that we could reconvert any decimal fraction to an equivalent common fraction with any chosen denominator. For example,

$$0.80 = \frac{80}{100} = \frac{40}{50} = \frac{20}{25} = \frac{16}{20} = \frac{8}{10} = \frac{4}{5} = \frac{2}{2.5} = \frac{1}{1.25}\text{, etc.}$$

These procedures offer a clue to what is proposed as a method for assessing detailed probabilities from summarized data in which no two records are alike, yet which do have some important elements in common.

b. <u>A symmetrical climatic frequency distribution</u>

In Seoul, Korea, during a 10-July period (310 July days) the daily mean (DMn) temperature was 77°F, the absolute minimum (AbMi) was 57°F and the absolute maximum (AbMx) was 97°F (5, p. 299). Because it lies midway between the extremes, the value of the mean is 50 on the 100-unit scale. A shorter way of stating that relationship is to call 50 a <u>converted mean</u> (CMn).*

Hourly distribution of temperature in Seoul during July is as follows: 1% of the time, 62°F or below; 10% of the time, 67°F or below; 50% of the time, 77°F or below; 90% of the time, 86°F or below; and 99% of the time, 94°F or below. Those expected hourly frequencies happen to be quite symmetrically (normally) distributed, and correspond well to the CMn 50 frequency pattern on the nomograph which is derived from the well-established normal frequency distribution familiar to statisticians.

c. <u>A strongly skewed climatic frequency distribution</u>

However, most distributions are asymmetrical (skewed). That is, their CMn is higher or lower than 50. An example of this is the April rainfall in New Orleans. At New Orleans during a 10-April period (300 April days in 10 years) the monthly mean (MoMn) rainfall was 4.94", and the 1-day maximum (1-day Mx) was 5.89". From the given data, by use of the nomograph, it was found that the converted daily mean (CDMn) pattern was 3. The expected 1-day maximum rainfall on the average was as follows: 1-day in 10 Aprils (1/300): 5.89"; 1 day in 5 Aprils (1/150): 4.35"; 1 day in 50 Aprils (1/1500): 8.60"; 1 day in 100 Aprils (1/3000): 9.90". (See Appendix B for detailed solution and computation of this example.)

The frequency thus described is so far from symmetrical that it would be hard to deal with by reference to normal probability distributions. But the nomograph breaks it down easily into a clear statement of probabilities.

d. <u>Range of converted mean values from these studies</u>

CMn values of the climatic frequency records, used in setting up the General-purpose type Nomograph developed in this and previous studies, have spanned the range 30 to 70 in temperature studies (5), and 1 to 14 in a precipitation study (7). Evident symmetry of curves in the basic section of the nomograph (Figure 1) has permitted its completion in the CMn 15 to 29 and 71 to 100 zones with considerable confidence, even though few actual climatic distributions probably fall in the CMn

*See Appendix A for Abbreviations

70 to 100 range. Symmetry of pattern in the basic section of Figure 1 seems due to the intended and actual near-equivalence of predictive distributions to the actual frequency distributions of climatic observations on which the nomograph is based, and thus by analogy, their equivalence to actual distributions at climatic stations published only in summarized form. However, present proof of the validity of the basic section of the nomograph will be limited here to examples of the empirical tests used in this and prior studies.

PART II. THE GENERAL-PURPOSE NOMOGRAPH

1. Its source and evolution

The integration of the nomographs used in the two studies mentioned in Part I, together with conclusions derived from these two investigations (5, 7) and associated extrapolations, resulted in a prototype general-purpose nomograph similar to Figure 1. After testing and modifying the prototype by use of numerous actual frequency distributions from world-wide sources, both of hourly temperature and 1-day maximum rainfalls, the refined instrument Figure 1 evolved. The frequency distribution of converted predictive values (CPrV), as represented by the prediction pattern of each of the converted means (CMns 1 to 100) and associated converted predictive values (CPrV 0 to 100), were critically examined by use of 4 different types of probability scales.* An attempt was made to devise a mathematical model from which the 100 CMn patterns of the nomograph could be derived. But this did not materialize. Consequently, the completed nomograph is empirically constructed, almost entirely. However, values for CMn 50 and associated CPrV's closely approximate the values taken from a normal frequency table.

2. Description of Nomograph and tabular equivalent

a. Basic section

(1) The nomograph

The square within which the Basic Section of the nomograph is drawn measures 100 units both horizontally and vertically. The vertical lines represent 101 (0 to 100, inclusive) converted predictive values (CPrV). The horizontal lines represent 101 (0 to 100, inclusive) converted means (CMn), and the converted predictive frequency distributions (CPrV) associated with each of them. The curved percentage frequency lines intersect both the CMn and CPrV lines and thus identify the CPrV's associated with particular probability values on each of the 101 CMn patterns. Each of the 101 CMn's on the nomograph is associated with a specific pattern of CPr values. For example, from left to right, the

*Probability Scales:
(1) Normal Probability Scale
(2) Normal-Log Probability Scale
(3) Skew-Log Probability Scale (Lackey, reference 8, Fig. 3)
(4) Extreme Probability Scale (Gumbel, reference 4)

FIGURE 1 - GENERAL-PURPOSE PREDICTIVE NOMOGRAPH: CONVERTED MEANS (CMn) AND ASSOCIATED CONVERTED PREDICTIVE VALUES (CPrV)

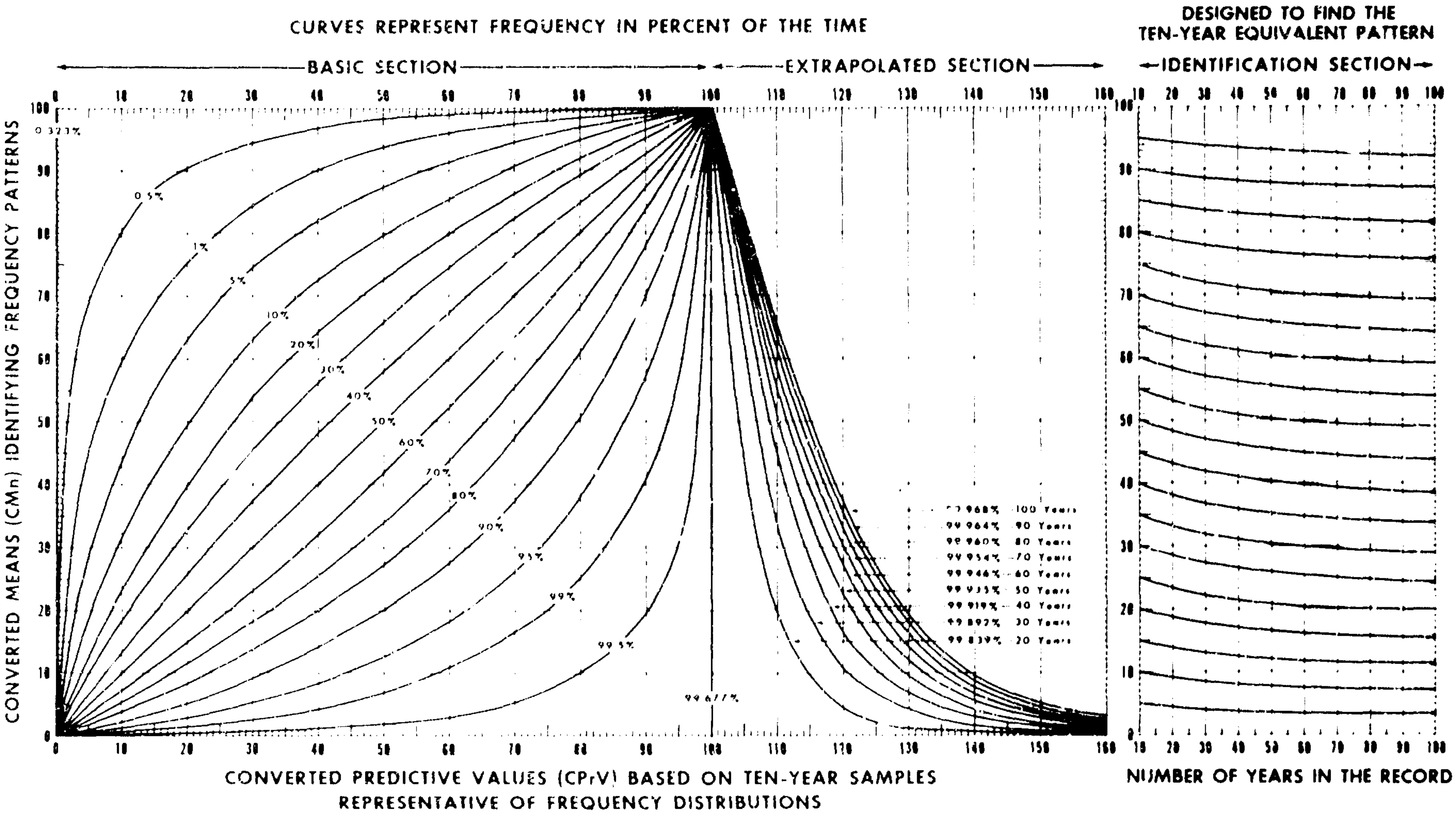

Figure 1

horizontal line of the CMn 60 pattern is crossed by more than a dozen curved percentage frequency lines at CPr values (vertical lines) as follows:

0.5% of the time, CPrV 3	10% of the time, CPrV 27
1% of the time, CPrV 11	20% of the time, CPrV 36
5% of the time, CPrV 18	99% of the time, CPrV 95
	99.5% of the time, CPrV 98.

The 0.323% and 99.677% are the minimum and maximum CPr values, respectively, for the period of observation (10 years). The diagonal (lower left to upper right) defines the asymmetry of each of the CMn patterns and identifies the predictive pattern for each of the 101 cumulative series.

(2) The table

The predictive features of the nomograph are numerically represented in their entirety in Table I. For example, the CPrV 90% column, Basic Section, contains the 101 CPrV's, each associated with 25 curved percentile lines on the nomograph. It is easy to see in the numerical table how each of the predictive patterns differs from every other one, and that each cumulative series in the Basic Section accumulates to 100.

The diversity of the frequency patterns that the nomograph (Fig. 1) and associated table (Table I) afford is illustrated diagrammatically by the three curves in Figure 2.

FIGURE 2: DIAGRAMMATIC SKETCH OF THREE REPRESENTATIVE PATTERNS OF CONVERTED FREQUENCY DISTRIBUTIONS

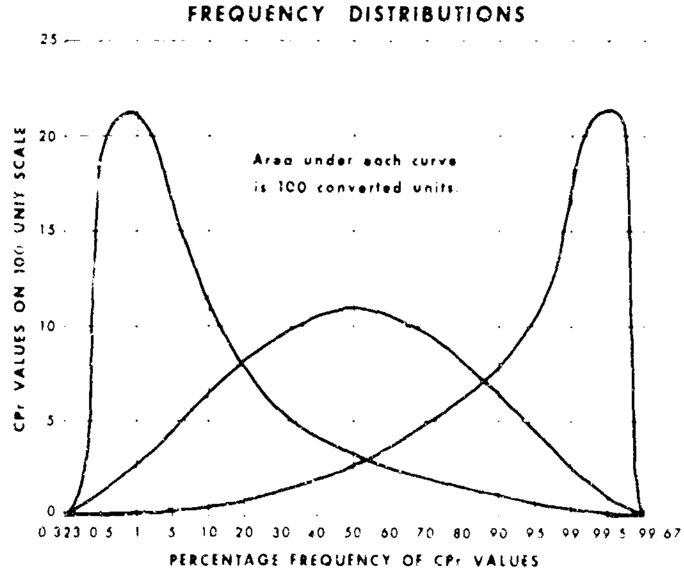

Figure 2

Table I: Tabular Equivalent of General-Purpose Nomograph:
Converted Means (CMn) and Associated Converted Predictive Values (CPrV)

CPrV's in Percentages Based on Ten Samples, Representative of Frequency Distributions of a Given Kind*

Basic Section

CMns	0.323%	0.5%	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%	99.5%
100	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
99	0	60	80	92	94	95	97	98	99	99	99	100	100	100	100	100
98	0	45	72	82	88	92	94	96	98	98	99	99	99	100	100	100
97	0	40	66	80	85	90	93	95	97	97	98	98	98	99	99	99
96	0	36	60	76	83	87	92	94	96	96	97	98	98	[illegible]	99	99
95	0	32	55	73	80	85	90	93	95	96	97	97	98	98	99	99
94	0	29	51	66	[illegible]	84	88	91	94	95	97	97	98	98	99	99
93	0	25	47	64	75	82	86	90	93	95	96	97	98	98	99	99
92	0	21	44	61	73	80	84	89	92	94	96	97	98	98	99	99
91	0	20	42	59	70	78	83	88	91	93	95	96	97	98	98	99
90	0	19	40	56	68	76	81	87	90	92	94	96	97	98	98	99
89	0	18	38	54	67	75	79	85	89	91	93	95	97	98	98	99
88	0	16	36	52	64	73	78	84	88	90	92	95	97	97	98	99
87	0	15	34	49	62	71	77	83	87	90	92	94	96	97	98	99
86	0	14	32	47	61	69	75	81	86	89	90	93	96	97	98	99
85	0	13	31	45	59	67	74	80	85	88	91	93	96	97	98	99
84	0	12	30	43	57	65	72	78	84	89	90	93	96	97	98	99
83	0	11	28	41	55	63	70	77	83	87	89	91	95	96	98	99
82	0	11	27	39	53	62	69	76	82	86	88	91	95	96	98	99
81	0	10	25	38	52	61	68	75	81	85	87	91	95	96	98	99
80	0	10	24	37	51	60	[illegible]	[illegible]	[illegible]	84	88	91	94	96	98	99
79	0	10	23	35	49	58	65	73	79	84	88	91	94	96	98	99
78	0	9	22	33	47	57	62	72	78	83	87	90	94	96	98	99
77	0	9	22	32	46	56	63	71	77	82	86	90	93	96	98	99
76	0	8	21	31	45	54	62	70	76	81	85	89	93	95	97	99
75	0	7	20	30	44	53	60	68	75	80	84	87	92	95	97	99

Extrapolated Section**

CMns	10 yrs 99.677%	20 yrs 99.839%	30 yrs 99.892%	40 yrs 99.919%	50 yrs 99.935%	60 yrs 99.946%	70 yrs 99.954%	80 yrs 99.960%	90 yrs 99.964%	100 yrs 99.968%
100	100 / 100	100	100	100	100	100	100	100	100	100
99	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	101 / 98.0
98	100 / 98.0	100 / 98.0	100 / 98.0	100 / 98.0	100 / 98.0	100 / 98.0	100 / 98.0	100 / 98.0	101 / 97.0	101 / 97.0
97	100 / 97.0	100 / 97.0	100 / 97.0	100 / 97.0	100 / 97.0	101 / 96.0	101 / 96.0	101 / 96.0	101 / 96.0	102 / 95.1
96	100 / 96.0	100 / 96.0	100 / 96.0	100 / 96.0	101 / 95.1	101 / 95.1	101 / 95.1	101 / 95.1	102 / 94.1	102 / 94.1
95	100 / 95.0	100 / 95.0	100 / 95.0	101 / 94.6	101 / 94.6	101 / 94.6	102 / 93.1	102 / 93.1	102 / 93.1	102 / 93.1
94	100 / 94.0	100 / 94.0	100 / 94.0	101 / 93.7	101 / 93.7	101 / 93.7	102 / 92.2	102 / 92.2	102 / 92.2	103 / 91.3
93	100 / 93.0	100 / 93.0	100 / 93.0	101 / 92.1	101 / 92.1	102 / 91.2	102 / 91.2	102 / 91.2	102 / 91.2	103 / 90.3
92	100 / 92.0	100 / 92.0	101 / 91.1	101 / 91.1	102 / 90.2	102 / 90.2	102 / 90.2	102 / 90.2	103 / 89.3	103 / 89.3
91	100 / 91.0	100 / 91.0	101 / 90.1	101 / 90.1	102 / 89.2	102 / 89.2	102 / 89.2	103 / 88.3	103 / 88.3	103 / 88.3
90	100 / 90.0	100 / 90.0	101 / 89.1	101 / 89.1	102 / 88.2	102 / 88.2	102 / 88.2	103 / 87.4	103 / 87.4	103 / 87.4
89	100 / 89.0	100 / 89.0	101 / 88.1	101 / 88.1	102 / 87.3	102 / 87.3	102 / 87.3	103 / 86.4	103 / 86.4	103 / 86.4
88	100 / 88.0	101 / 87.1	102 / 86.3	102 / 86.3	[illegible] / 86.3	102 / 86.3	103 / 85.4	103 / 85.4	103 / 85.4	103 / 85.4
87	100 / 87.0	101 / 86.1	102 / 85.3	102 / 85.3	102 / 85.3	103 / 84.5	103 / 84.5	103 / 84.5	104 / 83.7	104 / 83.7
86	100 / 86.0	101 / 85.1	102 / 84.3	102 / [illegible]	103 / [illegible]	103 / 83.5	103 / 83.5	103 / 83.5	104 / 82.6	104 / 82.6
85	100 / 85.0	101 / 84.2	102 / 83.3	103 / 82.5	103 / 82.5	103 / 82.5	103 / 82.5	104 / 81.7	104 / 81.7	105 / 81.0
84	100 / 84.0	101 / 83.2	102 / 82.4	103 / 81.6	103 / 81.6	103 / 81.6	104 / 80.8	104 / 80.8	104 / 80.8	105 / 80.0
83	100 / 83.0	101 / 82.2	102 / 81.4	103 / 80.6	103 / 80.6	104 / 79.8	104 / 79.8	105 / 79.0	105 / 79.0	105 / 79.0
82	100 / 82.0	101 / 81.1	102 / 80.4	103 / 79.6	103 / 79.6	104 / 78.8	104 / 78.8	105 / 78.1	105 / 78.1	105 / 78.1
81	100 / 81.0	101 / 80.2	102 / 79.4	103 / 78.6	104 / 77.9	104 / 77.9	105 / 77.1	105 / 77.1	105 / 77.1	106 / 76.4
80	100 / 80.0	101 / 79.2	102 / 78.4	103 / 77.7	104 / 76.9	105 / 76.2	105 / 76.2	105 / 76.2	106 / 75.5	106 / 75.5
79	100 / 79.0	101 / 78.2	102 / 77.5	103 / 76.7	104 / 76.0	105 / 75.2	105 / 75.2	106 / 74.5	106 / 74.5	106 / 74.5
78	100 / 78.0	101 / 77.2	102 / 76.5	104 / 75.0	104 / 75.0	105 / 74.3	105 / 74.3	106 / 73.6	107 / 72.9	107 / 72.9
77	100 / 77.0	102 / 75.4	103 / 74.8	104 / 74.0	105 / 73.3	105 / 73.3	106 / 72.6	106 / 72.6	107 / 72.0	107 / 72.0
76	100 / 76.0	102 / 74.5	103 / 73.8	104 / 73.1	105 / 72.4	105 / 72.4	107 / 71.0	107 / 71.0	107 / 71.0	108 / 70.4
75	100 / 75.0	102 / 73.5	103 / 72.8	105 / 71.4	106 / 70.8	106 / [illegible]	108 / 69.4	108 / 69.4	108 / 69.4	108 / 69.4

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.

**In the Extrapolated Section, values more than 100 are [illegible] than 100 are the Period Converted Means. $PCMn = \frac{100\ CMn}{CPrV}$

For CMn 90, for example, the 50-year PCMn is $\frac{100 \times 90}{102}$ or 88.2

Table I (continued)
Tabular Equivalent of General-Purpose Nomograph:
Converted Means (CMn) and Associated Converted Predictive Values (CPrV)

CPrV's in Percentages Based on Ten Samples, Representative of Frequency Distributions of a Given Kind*

	Basic Section																Extrapolated Section**									
CMns	0.323%	0.5%	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%	99.5%	10 yrs 99.6[illegible]%	20 yrs 99.8[illegible]%	30 yrs 99.892%	40 yrs 99.919%	50 yrs 99.935%	60 yrs 99.946%	70 yrs 99.954%	80 yrs 99.960%	90 yrs 99.964%	100 yrs 99.968%
74	0	7	18	29	42	52	58	66	74	79	84	87	92	95	97	99	100	102	103	105	105	106	107	107	108	108
																	74.0	72.5	71.9	70.5	70.5	69.8	69.1	69.1	68.5	68.5
73	0	6	17	29	41	50	57	65	73	78	83	87	91	94	97	99	100	102	103	105	105	106	107	107	108	108
																	73.0	71.6	70.9	69.5	69.5	68.9	68.2	68.2	67.6	67.6
72	0	6	17	28	40	49	56	65	72	77	83	87	91	94	97	99	100	102	103	105	105	106	107	107	108	109
																	72.0	71.6	70.9	69.5	69.5	68.9	68.2	68.2	67.6	67.0
71	0	6	16	27	38	48	56	64	71	77	82	86	90	94	97	99	100	102	103	105	105	107	107	107	109	109
																	71.0	69.7	68.9	67.6	67.6	66.4	66.4	66.4	65.1	65.1
70	0	5	16	26	37	47	55	63	70	76	81	86	90	94	97	99	100	102	104	105	106	107	107	108	109	109
																	70.0	68.6	67.3	66.7	66.0	65.4	65.4	64.8	64.2	64.2
69	0	5	15	25	36	46	54	62	69	78	81	86	89	94	97	99	100	102	104	105	106	107	107	108	109	109
																	69.0	67.6	66.3	65.7	65.1	64.5	64.5	63.9	63.3	63.3
68	0	5	15	24	35	44	53	61	68	75	80	85	89	94	97	99	100	102	104	105	106	107	107	108	109	110
																	68.0	66.7	65.4	64.8	64.2	63.6	63.6	63.0	62.4	61.8
67	0	4	14	23	34	43	52	60	67	73	79	84	89	94	97	99	100	102	104	106	106	107	107	108	109	110
																	67.0	65.7	64.4	63.2	63.2	62.6	62.6	62.0	61.5	60.9
66	0	4	14	22	33	42	50	59	66	72	79	83	88	93	96	99	100	102	104	106	107	108	108	109	110	110
																	66.0	64.7	63.5	62.3	61.7	61.1	61.1	60.6	60.0	60.0
65	0	4	13	21	32	41	49	58	65	71	78	83	88	93	96	99	100	103	105	106	107	108	108	109	110	110
																	65.0	63.1	61.9	61.3	60.7	60.1	60.1	59.6	59.1	59.1
64	0	4	13	21	31	40	48	57	64	71	78	83	87	93	96	99	100	103	105	106	107	108	109	109	110	111
																	64.0	62.1	61.0	60.4	59.8	59.3	58.7	58.7	58.2	57.7
63	0	4	12	20	30	39	47	56	63	70	77	82	87	92	96	99	100	103	105	106	108	108	109	109	110	111
																	63.0	61.1	60.0	59.4	58.3	58.3	57.8	57.8	57.2	56.8
62	0	3	11	20	29	38	46	55	62	69	76	81	86	92	96	99	100	103	105	107	108	108	109	110	111	111
																	62.0	60.2	59.0	57.9	57.4	57.4	56.9	56.4	55.9	55.9
61	0	3	11	19	28	37	45	53	61	68	75	80	86	92	95	99	100	103	105	107	108	109	109	110	111	112
																	61.0	59.2	58.1	57.0	56.5	56.0	56.0	55.5	55.0	54.5
60	0	3	11	18	27	36	44	52	60	67	74	79	85	91	95	98	100	103	105	107	108	109	110	110	111	112
																	60.0	58.3	57.1	56.1	55.6	55.0	54.5	54.5	54.1	53.6
59	0	3	10	18	27	35	43	50	59	66	73	78	85	91	95	98	100	103	106	107	108	109	110	110	111	112
																	59.0	57.3	55.7	55.1	54.6	54.1	53.6	53.6	53.2	52.7
58	0	3	10	17	26	34	42	49	58	65	72	78	84	90	95	98	100	103	106	107	109	109	110	111	112	113
																	58.0	56.3	54.7	54.2	53.2	53.2	52.7	52.2	51.8	51.3
57	0	3	9	16	26	34	41	48	57	64	71	77	84	90	95	98	100	103	106	108	109	110	110	111	112	113
																	57.0	55.3	53.8	52.8	52.3	51.8	51.8	51.4	50.9	50.4
56	0	3	9	16	25	32	40	47	56	63	70	76	83	90	95	98	100	104	106	108	109	110	111	111	112	113
																	56.0	53.8	52.8	51.9	51.4	50.9	50.5	50.5	50.0	49.6
55	0	2	9	15	24	31	39	47	55	62	70	76	83	89	95	98	100	104	106	108	109	110	111	112	113	113
																	55.0	52.9	51.9	50.9	50.5	50.0	49.5	49.1	48.7	48.7
54	0	2	8	15	24	30	38	46	54	61	69	75	82	89	95	98	100	104	106	108	109	110	111	112	113	114
																	54.0	51.9	50.9	50.0	49.5	49.1	48.6	48.2	47.8	47.4
53	0	2	8	14	23	29	37	45	54	60	68	75	82	88	94	98	100	104	106	108	110	111	112	113	114	114
																	53.0	51.0	50.0	49.1	48.2	47.7	47.3	46.9	46.5	46.5
52	0	2	7	14	22	29	36	44	53	59	67	74	81	88	94	98	100	104	107	108	110	111	112	113	114	114
																	52.0	50.0	[illegible]	48.1	47.3	[illegible]	46.4	46.0	45.6	45.6
51	0	2	7	14	22	28	35	43	51	58	66	73	80	87	94	98	100	104	107	109	110	111	112	114	115	115
																	51.0	49.0	47.7	46.8	46.4	45.9	45.5	44.7	44.3	44.3
50	0	2	7	13	21	27	34	42	50	57	65	72	79	87	94	98	100	104	107	109	110	111	113	114	115	115
																	50.0	49.1	46.7	45.9	45.5	45.0	44.2	43.9	43.5	43.5
49	0	2	7	13	20	26	33	40	49	56	64	71	79	86	93	98	100	104	107	109	110	111	113	114	115	115
																	49.0	47.1	45.6	45.0	44.5	44.1	43.4	43.0	42.6	42.6

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.

**In the Extrapolated Section, values more than 100 are the Extrapolated CPrV's. Values less than 100 are the Period Converted Means. $PCMn = \frac{100\ CMn}{CPrV}$

For CMn 90, for example, the 50-year PCMn is $\frac{100 \times 90}{102}$ or 88.2

Table I (continued)
Tabular Equivalent of General-Purpose Nomograph:
Converted Means (CMs) and Associated Converted Predictive Values (CPrV)

CPrV's in Percentages Based on Ten Samples, Representative of Frequency Distributions of a Given Kind*

	Basic Section																Extrapolated Section**									
																	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	60 yrs	70 yrs	80 yrs	90 yrs	100 yrs
CMs	0.323%	0.5%	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%	99.5%	99.677%	99.839%	99.892%	99.919%	99.935%	99.946%	99.954%	99.960%	99.964%	99.968%
48	0	2	6	12	20	26	32	40	48	55	64	70	78	86	93	98	100	105	107	110	111	112	114	115	116	116
																	48.0	45.7	44.9	43.6	43.2	42.9	42.1	41.7	41.4	41.4
47	0	2	6	11	19	25	32	39	47	55	63	70	78	85	92	98	100	105	107	110	111	112	114	115	116	116
																	47.0	44.8	43.9	42.7	42.3	42.0	41.2	40.9	40.5	40.5
46	0	2	6	11	18	24	31	38	46	54	62	69	77	85	92	98	100	105	107	110	111	112	114	115	116	116
																	46.0	43.8	43.0	41.8	41.4	41.1	40.4	40.0	39.7	39.7
45	0	2	5	10	17	24	30	37	45	53	61	68	76	84	92	97	100	105	107	110	111	113	114	115	116	117
																	45.0	42.9	42.1	40.9	40.5	39.8	39.5	39.1	38.8	38.5
44	0	2	5	10	16	23	29	36	44	52	60	67	76	84	92	97	100	105	108	110	112	113	115	116	117	117
																	44.0	41.9	40.7	40.0	39.3	38.9	38.3	37.9	37.6	37.6
43	0	2	5	10	16	21	27	35	43	51	59	66	75	83	91	97	100	105	108	110	112	113	115	116	117	117
																	43.0	41.0	39.9	39.1	38.4	38.1	37.4	37.1	36.8	36.8
42	0	2	4	9	15	20	26	35	42	50	58	66	74	83	91	97	100	105	108	111	113	114	115	117	118	118
																	42.0	40.0	38.9	37.8	37.2	36.8	36.5	35.9	35.6	35.6
41	0	2	4	9	15	20	26	34	41	48	57	65	73	82	90	97	100	106	109	111	113	114	116	117	118	113
																	41.0	38.7	37.6	36.9	36.3	36.0	35.3	35.0	34.7	34.7
40	0	1	4	9	15	20	26	32	40	46	56	64	72	81	89	97	100	106	109	111	113	115	116	117	118	119
																	40.0	37.7	36.7	36.0	35.4	34.8	34.5	34.2	33.9	33.6
39	0	1	4	8	14	19	25	31	39	46	55	63	72	81	89	97	100	106	109	112	113	115	116	117	119	119
																	39.0	36.8	35.8	34.8	34.5	33.9	33.6	33.3	32.8	32.8
38	0	1	4	8	14	19	24	31	38	45	54	62	71	80	88	96	100	106	109	112	114	116	117	118	119	120
																	38.0	35.8	34.9	33.9	33.3	32.8	32.5	32.2	31.9	31.7
37	0	1	4	8	13	18	23	30	37	45	53	61	70	80	88	96	100	106	109	112	114	116	117	118	119	120
																	37.0	34.9	33.9	33.0	32.4	31.9	31.6	31.4	31.1	30.8
36	0	1	3	7	13	18	22	29	36	44	52	60	69	79	87	96	100	106	110	113	114	117	118	119	120	121
																	36.0	34.0	32.7	31.9	31.6	30.8	30.5	30.3	30.0	29.8
35	0	1	3	7	12	17	21	28	35	43	51	59	68	78	87	96	100	106	110	113	115	117	118	119	120	121
																	35.0	33.0	31.8	31.0	30.4	29.9	29.7	29.4	29.2	28.9
34	0	1	3	7	12	17	21	27	34	42	50	58	67	77	87	96	100	107	110	113	115	117	119	119	121	122
																	34.0	31.8	30.9	30.0	29.6	29.1	28.6	28.6	28.1	27.9
33	0	1	3	6	11	16	20	26	34	41	49	57	66	77	86	96	100	107	110	113	116	118	119	120	121	122
																	33.0	30.8	30.0	29.2	28.4	28.0	27.7	27.5	27.3	27.0
32	0	1	3	6	10	15	19	25	33	40	48	56	65	76	85	95	100	107	110	114	116	118	119	120	121	122
																	32.0	29.9	29.1	28.1	27.6	27.1	26.9	26.7	26.4	26.2
31	0	1	3	6	9	15	19	25	32	39	47	55	64	76	85	95	100	107	111	114	117	119	120	120	122	123
																	31.0	29.0	27.9	27.2	26.5	26.1	25.8	25.8	25.4	25.2
30	0	1	3	6	9	14	18	24	30	38	45	53	63	75	84	95	100	107	111	114	117	119	120	121	122	123
																	30.0	29.0	27.0	26.3	25.7	25.2	25.0	24.8	24.6	24.4
29	0	1	3	5	9	14	18	23	28	37	44	52	62	74	84	95	100	107	111	114	117	119	121	122	123	123
																	29.0	27.1	26.1	25.4	24.8	24.4	24.0	23.8	23.6	23.6
28	0	1	2	5	8	13	17	22	27	36	43	51	61	73	83	94	100	108	112	115	118	120	122	122	123	124
																	28.0	25.9	25.0	24.3	23.7	23.3	23.0	23.0	22.8	22.6
27	0	1	2	5	8	12	17	21	27	35	42	50	59	71	82	94	100	108	112	115	118	120	122	123	124	124
																	27.0	25.0	24.1	23.5	22.9	22.5	22.1	22.0	21.8	21.8
26	0	1	2	4	7	12	16	20	26	34	41	49	58	70	81	93	100	108	112	115	119	120	123	123	124	125
																	26.0	24.1	23.2	22.6	21.8	21.6	21.1	21.1	21.0	20.1
25	0	1	2	4	7	11	15	19	25	32	39	47	57	69	80	93	100	108	113	116	119	121	123	124	125	126
																	25.0	23.1	22.1	21.6	21.0	20.7	20.3	20.2	20.0	19.8
24	0	1	2	4	7	11	14	18	24	31	37	51	56	68	79	93	100	109	113	116	119	122	123	125	126	127
																	24.0	22.0	21.2	20.7	20.2	19.7	19.5	19.2	19.0	18.9

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.

**In the Extrapolated Section, values more than 100 are the Extrapolated CPrV's. Values less than 100 are the Period Converted Means. $PCMs = \frac{100\ CMs}{CPrV}$

For CMs 90, for example, the 50-year PCMs is $\frac{100 \times 90}{102}$ or 88.2

Table I (continued)
Tabular Equivalent of General-Purpose Nomograph:
Converted Means (CMs) and Associated Converted Predictive Values (CPrV)

CPrV's in Percentages Based on Ten Samples, Representative of Frequency Distributions of a Given Kind*

Basic Section

CMs	0.323%	0.5%	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%	99.5%
23	0	1	2	4	6	10	13	17	23	30	36	47	54	66	78	92
22	0	1	2	4	6	10	12	17	22	[illegible]	35	[illegible]	[illegible]	[illegible]	77	[illegible]
21	0	1	2	4	5	9	12	16	21	28	34	42	51	64	76	92
20	0	1	2	4	5	9	11	15	20	26	33	40	50	63	75	90
19	0	1	2	4	5	8	10	15	19	25	31	39	48	61	74	90
18	0	0	2	3	5	8	9	14	18	24	30	37	47	60	73	89
17	0	0	2	3	5	7	9	14	17	23	29	35	46	58	72	88
16	0	0	2	3	5	7	8	13	16	21	27	33	44	56	70	87
15	0	0	2	3	5	6	8	12	15	20	25	32	42	54	67	86
14	0	0	2	3	4	6	8	11	14	19	24	30	40	53	65	85
13	0	0	1	2	4	5	7	10	13	17	22	28	38	51	64	84
12	0	0	1	2	4	5	7	9	12	16	21	27	36	49	63	83
11	0	0	1	2	3	4	6	8	11	15	20	25	34	47	60	82
10	0	0	1	2	3	4	5	7	10	14	18	24	32	44	58	80
9	0	0	1	2	3	4	5	6	9	13	17	23	30	41	56	78
8	0	0	1	1	2	3	4	5	8	12	15	21	28	39	54	76
7	0	0	1	1	2	3	4	5	7	11	14	19	26	37	52	74
6	0	0	1	1	2	3	3	4	6	9	12	16	23	33	49	71
5	0	0	0	1	1	2	3	4	5	7	10	14	20	30	44	68
4	0	0	0	1	1	2	2	3	4	6	9	12	17	26	39	63
3	0	0	0	1	1	1	2	3	3	5	7	10	15	22	35	58
2	0	0	0	0	1	1	1	2	2	4	6	8	12	18	28	55
1	0	0	0	0	0	0	1	1	1	2	3	5	6	8	20	40
0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0

Extrapolated Section**

CMs	10 yrs 99.677%	20 yrs 99.839%	30 yrs 99.892%	40 yrs 99.919%	50 yrs 99.935%	60 yrs 99.946%	70 yrs 99.954%	80 yrs 99.960%	90 yrs 99.964%	100 yrs 99.968%
23	100 23.0	109 21.1	113 20.4	117 19.8	120 19.2	122 18.9	124 18.5	125 18.3	127 18.1	127 18.1
22	100 22.0	109 20.2	114 [illegible]	117 18.8	120 18.3	123 17.9	124 17.7	127 17.3	128 17.2	128 17.2
21	100 21.0	110 19.1	114 18.4	117 17.9	121 17.4	123 17.1	125 16.8	127 16.5	128 16.4	128 16.4
20	100 20.0	110 19.2	115 17.4	118 16.9	121 16.5	124 16.1	126 15.9	127 15.7	128 15.6	129 15.5
19	100 19.0	110 17.3	115 16.5	118 16.1	122 15.6	124 15.3	126 15.1	128 14.8	129 14.7	129 14.7
18	100 18.0	111 16.2	116 15.5	119 15.1	122 14.8	125 14.4	127 14.2	128 14.1	130 13.8	131 13.7
17	100 17.0	111 15.3	116 14.7	120 14.2	123 13.8	126 13.5	127 13.4	129 13.2	131 13.0	132 12.9
16	100 16.0	112 14.3	117 13.7	120 13.3	123 13.0	127 12.6	128 12.5	129 12.4	131 12.2	132 12.1
15	100 15.0	112 13.4	117 12.8	120 12.5	124 12.1	127 11.8	128 11.7	130 11.5	132 11.4	133 11.3
14	100 14.0	113 12.4	118 11.9	121 11.6	125 11.2	128 10.9	129 10.9	131 10.7	132 10.6	134 10.4
13	100 13.0	113 11.5	119 10.9	122 10.7	126 10.3	129 10.1	130 10.0	132 9.8	134 9.7	135 9.6
12	100 12.0	114 10.5	119 [illegible]	123 9.8	127 9.4	130 9.2	132 9.1	134 9.0	135 8.9	136 8.8
11	100 11.0	114 9.6	120 9.2	124 8.9	128 8.6	131 8.4	133 8.3	135 8.1	137 8.0	138 8.0
10	100 10.0	115 8.7	121 8.2	125 8.0	130 7.7	132 7.6	135 7.4	136 7.4	138 7.2	139 7.2
9	100 9.0	115 7.8	122 7.4	126 7.1	131 6.9	133 6.8	137 6.6	138 6.5	140 6.4	141 6.4
8	100 8.0	116 6.9	123 6.5	127 6.3	132 6.1	135 5.9	138 5.8	140 5.7	141 5.7	143 5.6
7	100 7.0	117 6.0	124 5.6	129 5.4	133 5.3	137 5.1	139 5.0	141 5.0	143 4.9	145 4.8
6	100 6.0	[illegible] 5.1	126 4.8	[illegible] [illegible]	135 4.4	139 4.3	142 4.2	143 4.2	145 4.1	148 4.1
5	100 5.0	119 4.2	128 3.9	133 3.8	137 3.6	141 3.5	144 3.5	146 3.4	148 3.4	151 3.3
4	100 4.0	122 3.3	131 3.1	137 2.9	142 2.8	146 2.7	147 2.7	150 2.7	155 2.6	159 2.5
3	100 3.0	124 2.4	134 2.2	141 2.1	146 2.1	150 2.0	152 2.0	155 1.9	162 1.9	168 1.8
2	100 2.0	126 [illegible]	137 [illegible]	146 1.4	151 1.3	154 1.3	157 1.3	160 1.3	170 1.2	179
1	100 1.0	131 1.0	145 1.0	152 1.0	158 1.0	166 1.0	174	179	185	190
0	100 0.0									

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.

**In the Extrapolated Section, values more than 100 are the Extrapolated CPrV's. Values less than 100 are the Period Converted Means. $PCMs = \frac{100\ CMs}{CPrV}$

For CMs 90, for example, the 50-year PCMs is $\frac{100 \times 90}{102}$ or 88.2

b. Extrapolated section

(1) The nomograph

The 101 patterns of converted means (CMns) with their series of cumulated converted predictive values (CPrV's, 0 to 100) each represents a frequency distribution which becomes attenuated from the CMn toward its extremes, but does so at a decelerated rate. A frequency of 1 day in 1 January (1/31) is 3.23% of the time; 1 day in 10 Januaries (1/310) is 0.323% of the time; 1 day in 50 Januaries (1/1550) is .064% of the time; 1 day in 100 Januaries (1/3100) is 0.0323% of the time. This represents deceleration toward infinity. This decelerated decline of frequency in the 10-year record (CPrV 0 to 100 for each CMn value) is continued in the Extrapolated Section of the nomograph and extends to cover climatic frequency probabilities to 100 years (for particular months) by decade accretions.

Thus, we can trace the CMn 60 pattern (mentioned in Basic Section above) beyond the 100 CPrV limits to include 20- 30- 40- 50- 60- 70- 80- 90- and 100-year probabilities with reference to specified months. The extrapolated CPrV's above CPrV 100 for CMn 60 are 103, 105, 107, 108, 109, 110, 110, 111 and 112, respectively. The decelerated trends were derived by reference to long period extremes at numerous stations and also by use of several probability scales (see footnote, II, 1).

(2) The table

As in the Nomograph, the Extrapolated Section of the table is a continuation of the Basic Section, and extends to cover frequency probabilities by decades up to 100 years. Thus, for the CMn 60 pattern we follow the line 60 from the left margin to the required (e.g., 50-yr., 100-yr.) column heading in Extrapolated Section. Values more than 100 are the CPrV's. (Values less than 100 in Extrapolated Section are explained in the Identification Section comments below.)

c. Identification section

(1) The nomograph

The Basic Section of the nomograph was constructed from 10-year records. The trend of converted predictive values on the nomograph and in Table I, therefore, is geared only to 10-year summary records. What is to be done if one must use a 60-year summary record? The Identification Section is designed to cover such contingencies.* Let us assume that a given 60-year record has a converted mean (CMn) of 45. To identify

*See reference 9, Part IV, for full explanation of Identification Section.

the 10-year equivalent pattern for this CMn 45 in Figure 1, follow the vertical 60-year line (Identification Section) downward to horizontal line CMn 45. From here follow the nearest sloping line to the 10-year vertical line on the left margin. It emerges here on CMn 50. For prediction purposes the 10-year CMn 50 pattern of CPrV's should be used as the equivalent of the CMn 45 pattern of CPrV's associated with the 60-year record. In line manner the 10-year equivalent CMn pattern may be identified for the CMn pattern of CPr values for any length of record up to 100 years.

(2) The table

The same results may be achieved by use of Table I. Just follow down the 60-year column (Extrapolated Section) to the 60-year Period Converted Mean (PCMn) nearest 45. (PCMn's are the values in the Extrapolated Section that are less than 100.) The figure nearest to 45 in this column happens to be 45.0, which is the line or pattern of CPrV's associated with the 10-year CMn 50 (far left column). Therefore, the 10-year equivalent CMn 50 pattern of CPrV's is to be used in computing probabilities. (See Appendix C for example using Identification Section.)

PART III. SOME CLIMATOLOGY PREDICTIONS AND THEIR RELIABILITY

1. Assessing rainfall probabilities

Several examples of using the mean and two extremes with a General-purpose type Nomograph to predict frequency and probable amount of 1-day rainfall are given in Reference 7. An example of this type is solved in Appendix B.

2. Validation of certain rainfall predictions by handbook data

Manually tabulated and graphed climatic data for low, middle and high latitudes are given in three Army Handbooks: Cristobal, Canal Zone; Devils Lake, North Dakota; and Fort Churchill, Man. (10). Table II gives rainfall data from graphs in these handbooks ("Actual"). Also shown are corresponding predicted values ("Predicted") retrieved by use of the three items of summarized data (AbMx, AbMi and DMn), and the General-purpose Nomograph. The months chosen represent months of the wet or the dry seasons of the year. The predicted values run to 100 years. The graphed values cover only years of actual record.

The differences between the predicted and the actual (tabulated) are not greater than would be expected. In general, the predictions call for a few more days of low rainfall than the tabulated records indicate.

3. Other kinds of climatology problems

Using the mean and two extremes and the General-purpose Nomograph to assess hourly temperature probabilities is discussed in Reference 5 (mentioned above in I, 2b). An example of hourly temperature frequencies is also discussed later in this report (VI, 3) and a detailed solution given in Appendix C.

Summarized data are available for assessing probable percentage data for first killing frosts of Autumn, and last killing frosts of Spring; for the closing of harbors and rivers by ice in Winter and their opening in Spring; and for many other kinds of summarized atmospheric phenomena in which only mean and extremes are given.

Table II: Actual Rainfall Frequencies, Tabulated and Graphed, Compared with Predicted Probabilities*

Days in given mo. - (Ratio: / (Percent: / Months (One per year):		99/100 99% 1	90/100 90% 1	70/100 70% 1	50/100 50% 1	30/100 30% 1	10/100 10% 1	1/100 1.00% 1	1/310 .323% 10	1/620 .161% 20	1/930 .108% 30	1/1240 .0806% 40	1/1550 .0645% 50	1/1860 .0538% 60	1/2170 .0461% 70	1/2480 .0403% 80	1/2790 .0358% 90	1/3100 .0323% 100
Cristobal, C.Z.																		
Predicted	Oct	.00	.02	.25	.50	1.01	1.93	4.12	8.40	9.91	10.58	11.00	11.34	11.68	11.92	12.01	12.18	12.43
Actual	Oct	.00	.00	.03	.18	.65	1.75	6.00		8.00								
Predicted	Mar	.00	.02	.02	.03	.14	.29	.67	3.40	3.02	3.28	3.50	3.62	3.70	3.79	3.84	4.08	4.30
Actual	Mar	.00	.00	.00	.00	.02	.13	1.50		3.50								
Ft. Churchill																		
Predicted	Mar	.00	.00	.02	.07	.16	.31	.70	1.80	2.20	2.36	2.47	2.56	2.63	2.65	2.70	2.80	2.87
Actual	Mar	.00	.00	.00	.00	.00	.40	1.00		2.60								
Predicted	Sep	.00	.00	.00	.13	.24	.45		1.57	1.87	2.01	2.07	2.15	2.21	2.26	2.29	2.32	2.37
Actual	Sep	.00	.00	.00	.00	.04	.20	1.50		2.50								
Devil's Lake, N.D.																		
Predicted	Jun	.00	.03	.06	.11	.26	.49	1.12	2.87	3.50	3.76	3.93	4.08	4.19	4.22	4.31	4.43	4.56
Actual	Jun	.00	.00	.00	.00	.05	.30	1.50		2.50								
Predicted	Mar	.00	.00	.02	.03	.06	.13	.29	.84	1.03	1.13	1.18	1.22	1.26	1.28	1.30	1.36	1.41
Actual	Mar	.00	.00	.00	.00	.00	.06	.60		1.20								

*Predicted = Predicted rainfall amounts and frequencies, calculated from summarized data in Handbooks (AbMx, AbMi, DMn), using the General-purpose Nomograph

Actual = Data manually tabulated and graphed in the respective Handbook (10)

Underlined values are 1-day maxima for specified month, for period of summarized record.

Reading the table: At Cristobal (October), 30% of the time (30 days in 100) one may expect at least 1.01" rain; 0.108% of the time (1 day in 30 Octobers, or 1/930) one should expect at least 10.58"; and 0.461% of the time (1 day in 70 Octobers or 1/2170) one may expect at least 11.92".

PART IV. ILLUSTRATIVE USES FROM INDUSTRY AND PSYCHOLOGY

Many kinds of summarized data are amenable to this nomographic method by which frequency distributions may be resolved. If the mean, the extremes, and length of record are given, the percentage frequency and levels of occurrence may be retrieved or predicted with considerable confidence. Two examples are given below.

1. <u>Comparative screwdriver tensile strengths of slotted heads of valve caps</u>

A potential customer (such as the U. S. Army Materiel Command) desired to know the screwdriver tensile strength of samples of the slotted heads of valve caps of two competing companies. In the given situation the slotted heads of the screw caps could not tolerate tensions greater than 200 lb., and required a minimum strength of at least 140 lb. for satisfactory operations.

Company A: In a 34 valve-cap sample of this company the mean strength was 153 lb., the maximum was 181 lb., and the minimum was 130 lb.

Company B: In a 36 valve-cap sample of the competing company the mean strength was 138 lb., the maximum was 203 lb., and the minimum was 66 lb.

Using these data and the tabular equivalent of the General-purpose Nomograph (Table I), the frequency distribution of tensile strengths was predicted. The frequency distribution in Company A (34 sample records) followed pattern CMn 48. The frequency distribution in Company B (36 sample records) followed pattern CMn 57. The predicted distributions are given in Table III.

Table III. Predicted Frequency and Amount (in lb) of Tensile Strength of Slotted Heads of 2 Competing Valve Caps (Screwdriver Valve Tests)

Company	.0323%	1%	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%	99.84%	99.89%	99.92%	99.954%	99.968%
A	130	133	[140	142	145	149	153	156	161	16[illegible]	167	175	180	<u>181</u>	183	185	186]
B	66	77	99	109	118	127	138	[147	156	164	173	187	197]	201	<u>203</u>	206	210

Underlined figures represent maximum values
Brackets inclose tolerance range [140 - 200 lb]

It is evident from Table III that 90% of Company A valve caps were within the required range (140 to 200 lb.), and that only 50% of Company B valve caps were within this range.

It is conceded that it may seem odd to construct from climatic data a predictive nomograph, and then use it in application to industrial data. But we do use means, standard deviations, etc., regularly as universal measures of dispersion. It is suggested that patterns of asymmetry, in general, are amenable to many more applications.

2. Scores on Army Alpha Test

The summary of scores from an Army Alpha Test given to a group of 54 Army men was as follows: maximum score 201, mean score 172, and minimum score 126 (3). Assuming this to be representative of 10 repeated tests, what are the probable results to be expected at various percentages of the time?

In solving this problem, the converted mean of 61 is used (CMn = 61). Therefore the CPr values in the CMn 61 pattern of Table I (equivalent of the Nomograph) were used to compute the probable percentages of frequency scores. These were found to be: 10% of the men should score 147 or lower; 20%, 154 or lower; 30%, 160 or lower; 50%, 173 or lower; 70%, 182 or lower; 90%, 191 or lower. That is, only 10% of the men should score 191 or above.

If the test had included a larger proportion of easy questions, then the CMn might have been higher, perhaps as high as CMn 80 or 90. The converse probably would happen if there had been a larger proportion of difficult questions in the tests. Or if there had been a large number of such tests, the extremes would probably be more attenuated--perhaps having the maximum higher, and the minimum lower. Then a different nomographic pattern, selected by means of the Identification Section, would be used for predictive purposes, but the distribution pattern would still be approximately as asymmetrical.

PART V. THE ALTERNATIVE NOMOGRAPH

1. Essential data and theory for constructing and using

In summarizing data in which extremes are critical factors, it is often desirable to know the averages of the extremes measured. Therefore, mean maxima (MMx) and mean minima (MMi) for given month(s) are often listed in summary records. The extreme maximum and the extreme minimum temperature for January each usually occurs only once. On the other hand, in January over a period of 50 years there are 1550 daily maxima and 1550 daily minima. The averaging of these gives a January mean daily maximum (MDMx) and a January mean daily minimum (MDMi) each of which is a more stable value from which to measure frequency of daily extremes than any one of its numerous components. It is proposed, therefore, to construct an Alternative All-purpose Nomograph using these two means (MDMx and MDMi) as relatively stable anchors in the abbreviated record from which the frequency of oscillating extremes may be measured.

In such a nomograph the frequency distribution associated with the oscillating **daily minimum** would be measured, located by reference to a 100-unit scale extending from the converted mean daily maximum (CMDMx) = 100 to the absolute minimum (AbMi) = 0. Thus, the converted mean daily minimum (CMDMi) serves to identify the pattern of CPrV's to be used for predictive purposes.

For purposes of predicting the frequency patterns associated with daily maxima or minima, the range should perhaps be measured from one absolute extreme (e.g., AbMx) in a given period of time to the mean of the opposite extreme (e.g., MDMi) instead of measuring from one absolute extreme to the opposite absolute extreme as in Figure 1. We have in Figure 3 such a nomograph. Its construction and use are in most ways analogous to that of Figure 1 of the present study.

2. Previous studies used, and range of converted mean extremes

Two studies (6, 8) served chiefly as guides in constructing the prototype for Figure 3 (Alternative Nomograph). The CMn patterns for the former (CMDMi in reference 6) ranged from CMn 20 to CMn 55, and the CMn patterns for the latter (CMDMx in reference 8) ranged from CMn 36 to CMn 80. (The two series of patterns overlap from CMn 36 to CMn 55.) This left CMn 0 to 20 and CMn 80 to 100 to be developed. The extrapolations were achieved by use of several differing probability scales (see footnote II-2), by searching out some extreme types of distributions, and considering some unusual but theoretically possible situations. For example: a case in which either one or the other or both extremes in several or all of the distributions ran into stationary or fixed limits. Or a situation in which a very potent variable synchronized with other high variables only once or twice in a large number of distributions. In some such cases extremely skewed or asymmetrical distributions might, probably would, occur. In situations like this, converted mean patterns might run high, say 85 to 100 or perhaps low - 0 to 15.

FIGURE 3 - ALTERNATIVE PREDICTIVE NOMOGRAPH: CONVERTED MEAN EXTREMES (CMDMi OR CMDMx) AND ASSOCIATED CONVERTED PREDICTIVE VALUES (CPrV)

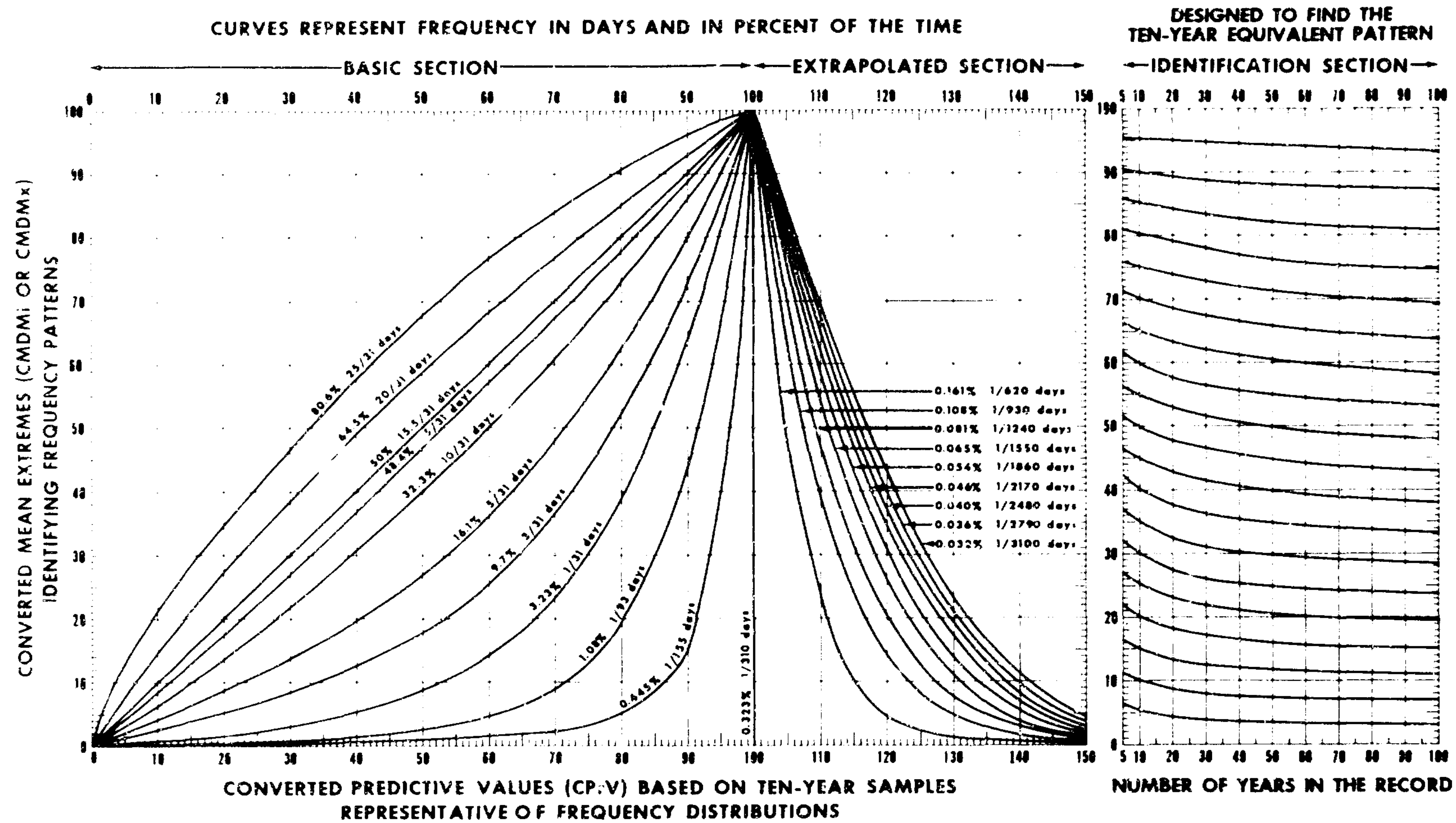

Figure 3

3. Examples of use in predicting

Reference 8 contains several examples of the use of a nomograph similar to this to predict probable frequency of occurrence of daily maximum temperatures. For these the summarized data are: AbMx, MDMx and MDMi. Reference 9 gives an example of predicting probable frequency of daily minimum temperatures. For these the essential data are: AbMi, MDMi and MDMx.

In part VI, 4 of this report January minimum temperature probabilities are given for certain degree quadrangles in Germany.

4. Tabular counterpart

In Table IV the predictive features of the Alternative Nomograph are numerically represented in their entirety. See Part II, 2 of this report, for a generalized explanation of the sections of the table.

5. Differences between the two nomographs

The nomographs are constructed from and used with different items of essential data, as explained above and summarized in VI, 2 below.

In the General-purpose Nomograph, the predictive curves are given in the usual percentages (1%, 5%, 10% 20% . . . 100%). In the Alternative Nomograph the predictive curves are given primarily in frequency in days (25/31, 20/31 . . . 1/3100) with the corresponding percentages (80.6%, 64.5% . . . 0.032%). The latter nomograph has certain advantages for solving climatology problems.

Of course it is immaterial whether the percent frequency curves are arranged from 0 to 100 or from 100 to 0, since on occasion each curve is used as value X or as 100 - X.

Table IV: Tabular Equivalent of Alternative Nomograph:
Converted Mean Extremes (CMDMd or CMDMx) and Associated Converted Predictive Values (CPrV)

CPrV's in Days-Per-Month and Percent of Time, Based on Samples, Representative of Frequency Distributions of a Given Kind*

CMDMd/ CMDMx	Basic Section 99.677% 31/31	80.6% 25/31	64.5% 20/31	48.4% 15/31	32.3% 10/31	16.1% 5/31	9.7% 3/31	3.23% 1/31	1.08% 1/93	0.645% 1/155	0.323% 1/310	Extrapolated Section** 0.161% 1/620	0.108% 1/930	0.081% 1/1240	0.065% 1/1550	0.054% 1/1860	0.046% 1/2170	0.040% 1/2480	0.036% 1/2790	0.032% 1/3100
100	0	100	100	100	100	100	100	100	100 100	100 100	100 100	100 100	100 100	100 100	100 100	100 100	100 100	100 100	100 100	100 100
99	0	97	98	99	99	100	100	100	100 99.0	100 99.0	100 99.0	100 99.0	100 99.0	100 99.0	100 99.0	100 99.0	100 99.0	100 99.0	100 99.0	100 99.0
98	0	95	97	98	99	99	99	100	100 98.0	100 98.0	100 98.0	100 98.0	100 98.0	100 98.0	100 98.0	100 98.0	100 98.0	100 97.0	101 97.0	101 97.0
97	0	92	96	97	98	99	99	99	100 97.0	100 97.0	100 97.0	100 97.0	100 97.0	100 97.0	100 97.0	100 97.0	101 96.0	101 96.0	101 96.0	101 96.0
96	0	90	94	97	97	98	99	99	100 96.0	100 96.0	100 96.0	100 96.0	100 96.0	101 95.0	101 95.0	101 95.0	101 95.0	101 95.0	101 95.0	101 95.0
95	0	90	93	96	97	98	98	99	100 95.0	100 95.0	100 95.0	100 95.0	100 95.0	101 94.1	101 94.1	101 94.1	101 94.1	101 94.1	101 94.1	102 93.1
94	0	85	92	95	96	97	98	99	99 95.9	100 94.0	100 94.0	100 94.0	101 93.1	101 93.1	101 93.1	101 93.1	102 92.2	102 92.2	102 92.2	102 92.2
93	0	84	90	94	95	97	98	99	99 94.9	100 93.0	100 93.0	100 93.0	101 92.1	101 92.1	102 91.2	102 91.2	102 91.2	102 91.2	102 91.2	102 91.2
92	0	83	89	93	95	96	97	98	99 93.9	100 92.0	100 92.0	100 92.0	101 91.1	101 91.1	102 90.2	102 90.2	102 90.2	102 90.2	103 89.3	103 89.3
91	0	81	88	92	94	96	97	98	99 91.9	100 91.0	100 91.0	100 91.0	101 90.0	102 89.2	102 89.2	102 89.2	103 88.3	103 88.3	103 88.3	103 88.3
90	0	80	87	91	93	95	97	98	99 91.0	100 90.0	100 90.0	101 89.1	101 89.1	102 88.2	102 88.2	103 87.4	103 87.4	103 87.4	103 87.4	103 87.4
89	0	78	85	90	92	95	96	98	99 89.9	100 89.0	100 89.0	101 88.1	101 88.1	102 87.3	102 87.3	103 86.4	103 86.4	103 86.4	103 86.4	104 85.5
88	0	76	84	90	92	94	96	98	99 88.8	99 88.8	100 88.0	101 87.1	101 87.1	102 86.3	103 85.4	103 85.4	103 85.4	104 84.6	104 84.6	104 84.6
87	0	75	83	89	91	94	96	97	99 87.9	99 87.9	100 87.0	101 86.1	102 85.3	102 85.3	103 84.5	103 84.5	104 83.7	104 83.7	104 83.7	104 83.7
86	0	72	82	88	90	93	95	97	98 87.8	99 86.9	100 86.0	101 85.1	102 84.3	102 84.3	103 83.5	104 82.7	104 82.7	104 82.7	104 82.7	105 81.9
85	0	72	80	87	89	93	95	97	98 86.7	99 85.9	100 85.0	101 84.2	102 83.3	103 82.5	103 82.5	104 81.7	104 81.7	105 81.0	105 81.0	105 81.0
84	0	70	79	86	88	92	95	96	98 85.7	99 84.8	100 84.0	101 83.2	102 82.4	103 81.6	104 80.8	104 80.8	105 80.0	105 80.0	105 80.0	105 80.0
83	0	69	78	85	88	92	94	96	98 84.7	99 83.8	100 83.0	101 82.2	102 81.4	103 80.6	104 79.8	105 79.0	105 79.0	105 79.0	106 78.3	106 78.3
82	0	67	77	84	87	91	94	96	98 83.6	99 82.8	100 82.0	101 81.1	102 80.4	103 79.6	104 78.8	105 78.1	105 78.1	106 77.4	106 77.4	106 77.4
81	0	66	75	83	86	90	93	96	98 83.5	99 81.8	100 81.0	101 80.2	102 79.4	103 78.6	104 77.8	105 77.1	106 76.4	106 76.4	106 76.4	107 75.7
80	0	65	74	82	85	90	93	95	98 81.6	99 80.8	100 80.0	101 79.2	102 78.4	104 76.9	105 76.2	105 76.2	106 75.5	106 75.5	107 74.8	107 74.8
79	0	63	73	81	85	89	93	95	97 31.4	99 79.8	100 79.0	102 77.5	103 76.7	103 76.7	104 76.0	105 75.2	106 74.5	106 74.5	107 73.8	107 73.8
78	0	62	72	80	84	89	92	94	57 80.4	99 78.8	100 78.0	102 76.5	103 75.7	104 75.0	105 74.3	105 74.3	106 73.6	106 73.6	107 72.9	107 72.9
77	0	61	71	79	83	88	92	94	97 79.4	99 77.8	100 77.0	102 75.5	103 74.8	104 74.0	105 73.3	105 73.3	106 72.6	107 72.0	107 72.0	108 71.3
76	0	60	70	78	82	88	91	94	97 78.4	99 76.7	100 76.0	102 74.5	103 73.8	104 73.1	105 72.4	106 71.7	106 71.7	107 71.0	107 71.0	108 70.4
75	0	58	68	78	82	87	91	93	96 78.1	99 75.8	100 75.0	102 73.5	103 72.8	104 72.1	105 71.4	106 70.8	107 70.1	107 70.1	108 69.4	108 69.4

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.
**In the Extrapolated Section, values more than 100 are the Extrapolated CPrV's. Values less than 100 are the Period Converted Mean.

$$PCMDMd = \frac{100\ CMDMd}{CPrV} \text{ or } PCMDMx = \frac{100\ CMDMx}{CPrV}$$

Table IV (continued)
Tabular Equivalent of Alternative Nomograph:
Converted Mean Extremes (CMEMi or CMEMx) and Associated Converted Predictive Values (CPrV)

CPrV's in Days-Per-Month and Percent of Time, Based on Samples, Representative of Frequency Distributions of a Given Kind*

CMEMi/ CMEMx	Basic Section 99.677% 31/31	80.6% 25/31	64.5% 20/31	48.4% 15/31	32.3% 10/31	16.1% 5/31	9.7% 3/31	3.23% 1/31	1.08% 1/93	0.645% 1/155	0.323% 1/310	Extrapolated Section** 0.161% 1/620	0.108% 1/930	0.081% 1/1240	0.065% 1/1550	0.054% 1/1860	0.046% 1/2170	0.040% 1/2480	0.036% 1/2790	0.032% 1/3100
74	0	57	67	77	81	87	90	93	96	99	100	102	103	104	105	106	107	107	108	109
									77.1	74.7	74.0	72.5	71.8	71.2	70.5	69.8	69.2	69.2	68.3	67.9
73	0	56	66	76	80	86	90	93	96	99	100	102	104	104	106	106	107	108	108	109
									76.0	73.7	73.0	71.6	70.2	70.2	68.9	68.9	68.2	67.6	67.6	67.0
72	0	55	65	75	79	86	90	92	96	98	100	102	104	105	106	107	107	108	109	109
									75.0	73.5	72.0	70.6	69.2	68.6	67.9	67.3	67.3	66.7	66.1	66.1
71	0	54	64	74	79	85	89	92	96	98	100	102	104	105	106	107	108	108	109	110
									74.0	72.4	71.0	69.6	68.3	67.6	67.0	66.4	65.7	65.7	65.1	64.5
70	0	53	62	73	77	84	89	92	96	98	100	102	104	105	106	107	108	109	109	110
									72.9	71.4	70.0	68.6	67.3	66.7	66.0	65.4	64.8	64.2	64.2	63.6
69	0	51	61	72	77	84	88	91	95	98	100	102	104	105	106	107	108	109	110	110
									72.6	70.4	69.0	67.6	66.3	65.7	65.1	64.5	63.9	63.3	62.7	62.7
68	0	50	60	71	76	83	88	91	95	98	100	103	104	105	106	107	108	109	110	111
									71.6	69.4	68.0	66.0	65.4	64.8	64.2	63.6	63.0	62.3	61.8	61.3
67	0	49	59	70	75	83	88	91	95	98	100	103	104	105	105	107	108	109	110	111
									70.5	68.4	67.0	65.0	64.4	63.8	63.2	62.6	62.0	61.5	60.9	60.4
66	0	48	58	69	74	82	87	91	95	98	100	103	105	106	107	108	109	110	110	111
									69.5	67.3	66.0	64.1	62.9	62.3	61.7	61.1	60.1	60.0	60.0	59.5
65	0	47	57	68	73	81	86	90	95	98	100	103	105	106	107	108	109	110	111	112
									68.4	66.3	65.0	63.1	61.9	61.3	60.7	60.2	59.6	59.1	58.6	58.0
64	0	46	56	67	73	81	86	90	95	98	100	103	105	106	108	109	110	110	111	112
									67.4	65.3	64.0	62.1	61.0	60.4	59.3	58.7	58.2	58.2	57.7	57.1
63	0	46	56	67	73	81	86	90	94	98	100	103	105	106	108	109	110	111	112	112
									67.0	64.3	63.0	61.2	60.0	59.4	58.3	57.7	57.3	56.8	56.3	56.3
62	0	45	54	65	71	80	85	89	94	98	100	103	105	106	108	109	110	111	112	113
									66.0	63.3	62.0	60.2	59.1	58.5	57.4	56.9	56.4	55.9	55.4	54.9
61	0	44	53	64	70	79	85	89	94	98	100	103	105	106	108	109	110	111	112	113
									64.9	62.2	61.0	59.2	58.1	57.6	56.5	56.0	55.5	55.0	54.5	54.0
60	0	42	51	63	69	78	84	89	94	97	100	104	106	107	108	110	111	111	112	113
									63.8	61.9	60.0	57.7	56.6	56.1	55.5	54.5	54.1	54.1	53.6	53.1
59	0	42	51	62	68	78	84	88	93	97	100	104	106	107	109	110	111	112	113	114
									63.4	60.8	59.0	56.7	55.7	55.1	54.1	53.6	53.2	52.9	52.2	51.8
58	0	41	49	61	67	77	83	88	93	97	100	104	106	107	109	110	111	112	113	114
									62.4	59.8	58.0	55.8	54.7	54.2	53.2	52.7	52.3	51.9	51.3	50.9
57	0	40	48	60	66	76	83	88	93	97	100	104	106	108	109	111	112	113	114	115
									61.3	58.8	57.0	54.2	53.8	52.8	52.3	51.4	50.9	50.4	50.0	49.6
56	0	39	47	59	66	76	82	87	93	97	100	104	106	108	110	111	112	113	114	115
									60.2	[illegible]	56.0	53.8	52.8	51.9	50.9	50.4	50.0	49.6	49.1	48.7
55	0	38	46	58	65	75	82	87	93	97	100	104	107	108	110	111	112	113	114	115
									59.1	56.7	55.0	52.9	51.4	50.9	50.0	49.5	49.1	48.7	48.2	47.8
54	0	37	45	57	64	74	81	86	92	97	100	104	107	108	110	111	112	113	115	116
									58.7	55.7	54.0	51.9	50.5	50.0	49.1	48.6	48.2	47.8	47.0	46.6
[illegible]	[illegible]	[illegible]	44	56	63	[illegible]	[illegible]	86	92	97	100	104	107	108	110	112	113	114	115	116
									57.6	54.6	53.0	51.0	49.5	49.1	48.2	47.3	46.9	46.5	46.1	45.7
52	0	35	43	55	62	73	80	86	92	96	100	104	107	109	111	112	113	114	115	116
									56.5	54.2	52.0	50.0	48.6	47.7	46.8	46.4	46.0	45.6	45.2	44.8
51	0	33	42	53	60	71	79	85	92	96	100	105	107	109	111	113	114	115	116	117
									55.4	53.1	51.0	48.6	47.7	46.8	45.9	45.1	44.7	44.3	44.0	43.6
50	0	33	41	53	60	71	79	85	91	96	100	105	107	109	111	113	114	115	116	117
									54.9	52.0	50.0	47.6	46.7	45.9	45.0	44.2	43.9	43.5	43.1	42.7

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.
**In the Extrapolated Section, values <u>more</u> than 100 are the Extrapolated CPrV's. Values <u>less</u> than 100 are the Period Converted Mean.

$$PCMEMi = \frac{100\ CMEMi}{CPrV} \text{ or } PCMEMx = \frac{100\ CMEMx}{CPrV}$$

Table IV (continued)
Tabular Equivalent of Alternative Nomograph:
Converted Mean Extremes (CMEMi or CMEMx) and Associated Converted Predictive Values (CPrV)

CPrV's in Days-Per-Month and Percent of Time, Based on Samples, Representative of Frequency Distributions of a Given Kind*

CMEMi/ CMEMx	Basic Section 99.67% 31/31	80.6% 25/31	64.5% 20/31	48.4% 15/31	32.3% 10/31	16.1% 5/31	9.7% 3/31	3.2% 1/31	1.08% 1/93	0.645% 1/155	0.323% 1/310	Extrapolated Section** 0.161% 1/620	0.108% 1/930	0.081% 1/1240	0.065% 1/1550	0.054% 1/1860	0.046% 1/2170	0.040% 1/2480	0.036% 1/2790	0.032% 1/3100
49	0	32	40	52	59	71	78	85	91 53.8	96 51.0	100 49.0	105 46.7	108 45.4	109 45.0	111 44.1	113 43.4	114 43.0	115 42.6	116 42.2	118 41.5
48	0	32	39	51	58	70	78	84	91 52.7	96 50.0	100 48.0	105 45.7	108 44.4	110 43.6	112 42.9	113 42.5	115 41.7	116 41.4	117 41.0	118 40.7
47	0	30	38	50	57	69	77	84	91 51.6	96 49.0	100 47.0	105 44.8	108 43.5	110 42.7	112 42.0	114 41.2	115 40.9	117 40.2	118 39.8	119 39.5
46	0	30	38	49	57	68	76	83	91 50.5	96 47.9	100 46.0	105 43.8	108 42.6	110 41.8	112 41.1	114 40.4	115 40.0	116 39.7	117 39.3	119 38.7
45	0	29	37	49	56	68	76	83	90 50.0	96 46.9	100 45.0	105 42.9	108 41.7	110 40.9	112 40.2	114 39.3	115 39.1	116 38.8	118 38.1	119 37.8
44	0	28	36	47	54	67	75	82	90 48.9	96 45.8	100 44.0	105 41.5	109 40.4	111 39.6	113 38.9	115 38.3	116 37.9	117 37.6	118 37.3	120 36.6
43	0	27	34	46	53	66	75	82	90 47.7	95 45.2	100 43.0	106 40.6	109 39.4	111 38.7	113 38.1	115 37.4	116 37.1	118 36.4	119 36.2	120 35.8
42	0	26	33	45	52	65	74	81	89 47.2	95 44.2	100 42.0	106 39.6	109 38.5	111 37.8	114 36.8	115 36.5	117 35.9	118 35.6	119 35.3	121 35.0
41	0	25	32	44	51	64	73	81	89 46.1	95 43.2	100 41.0	106 38.7	109 37.6	112 36.6	114 36.0	116 35.3	117 35.0	118 34.7	119 34.5	121 33.9
40	0	23	31	43	50	63	72	80	89 44.9	95 42.1	100 40.0	106 37.7	110 36.4	112 35.7	114 35.1	116 34.5	118 33.9	119 33.6	120 33.3	121 33.1
39	0	23	31	42	49	62	72	80	89 43.8	95 41.1	100 39.0	106 36.7	110 35.5	112 34.8	115 33.9	116 33.6	118 33.1	119 32.8	120 32.5	122 31.0
38	0	22	30	41	48	62	71	79	88 43.2	95 40.0	100 38.0	107 35.5	110 34.5	113 33.6	115 33.0	117 32.5	118 32.2	120 31.7	121 31.4	122 31.1
37	0	22	29	40	47	61	70	79	88 42.0	94 39.4	100 37.0	107 34.6	110 33.6	113 32.7	115 32.3	117 31.6	119 31.1	120 30.8	121 30.6	123 30.1
36	0	21	28	39	46	60	69	78	88 40.9	94 38.3	100 36.0	107 33.6	111 32.4	113 31.9	116 31.0	118 30.5	119 30.3	121 29.8	122 29.5	123 29.3
35	0	20	26	38	45	59	69	78	87 40.2	94 37.2	100 35.0	107 32.7	111 31.5	114 30.7	116 30.2	118 29.7	120 29.2	121 28.9	122 28.7	124 28.2
34	0	20	26	37	44	58	68	77	87 39.1	94 36.2	100 34.0	108 31.5	111 30.6	114 29.8	117 29.1	119 28.6	120 28.3	121 28.1	122 27.9	124 27.4
[illegible]	0	19	25	36	43	57	67	77	86 38.4	94 35.1	100 33.0	108 30.6	112 29.5	114 28.9	117 28.2	119 27.7	121 27.3	122 27.0	123 26.8	125 26.4
32	0	18	24	35	42	56	66	76	86 37.2	93 34.4	100 32.0	108 29.6	112 28.6	115 27.8	117 27.4	119 26.9	121 26.4	122 26.2	124 25.8	125 25.6
31	0	18	23	33	40	54	65	75	85 36.5	93 33.3	100 31.0	108 28.7	112 27.7	115 27.0	118 26.2	120 25.8	121 25.6	122 25.4	124 25.0	126 24.6
30	0	16	22	33	39	53	65	75	85 35.3	93 32.2	100 30.0	109 27.5	113 26.5	116 25.9	118 25.4	120 25.0	122 24.6	123 24.4	125 24.0	126 23.8
29	0	15	21	32	38	52	64	74	85 34.1	93 31.5	100 29.0	109 26.6	113 25.7	116 25.0	119 24.4	121 24.0	123 23.6	124 23.4	125 23.2	127 22.8
28	0	15	21	31	38	52	63	74	84 33.3	93 30.1	100 28.0	109 25.7	113 24.8	117 23.9	119 23.5	121 23.1	123 22.8	125 22.5	126 22.2	127 22.0
27	0	14	20	30	36	50	62	73	84 32.1	93 29.0	100 27.0	109 24.8	114 23.7	117 23.1	120 22.5	122 22.1	124 21.8	125 21.5	126 21.4	127 21.3
[illegible]	[illegible]	13	19	29	35	49	61	72	83 31.3	92 28.3	100 [illegible]	110 [illegible]	[illegible] [illegible]	117 22.2	120 21.7	122 21.3	125 20.8	[illegible] 20.6	[illegible] 20.5	128 20.3
25	0	13	18	28	34	48	59	71	83 30.1	92 27.2	100 25.0	110 22.7	115 21.7	118 21.2	120 20.8	123 20.3	125 20.0	126 19.8	127 19.7	128 19.4

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.
**In the Extrapolated Section, values <u>more</u> than 100 are the Extrapolated CPrV's. Values <u>less</u> than 100 are the Period Converted Mean.

$$PCMEMi = \frac{100\ CMEMi}{CPrV} \text{ or } PCMEMx = \frac{100\ CMEMx}{CPrV}$$

Table IV (continued)
Tabular Equivalent of Alternative Nomograph:
Converted Mean Extremes (CMDMi or CMDMx) and Associated Converted Predictive Values (CPrV)

CMDMi/ CMDMx	CPrV's in Days-Per-Month and Percent of Time, Based on Samples, Representative of Frequency Distributions of a Given Kind* Basic Section											Extrapolated Section**								
	99.67% 31/31	80.6% 25/31	64.5% 20/31	48.4% 15/31	32.3% 10/31	16.1% 5/31	9.7% 3/31	3.23% 1/31	1.08% 1/93	0.645% 1/155	0.323% 1/310	0.161% 1/620	0.108% 1/930	0.081% 1/1240	0.065% 1/1550	0.054% 1/1860	0.046% 1/2170	0.040% 1/2480	0.036% 1/2790	0.032% 1/3100
24	0	12	17	27	33	47	58	70	82	92	100	110	115	118	121	123	126	127	128	130
									29.3	26.1	24.0	21.8	20.9	20.3	19.8	19.5	19.0	18.9	18.8	18.5
23	0	11	17	26	32	45	57	70	82	92	100	110	115	119	122	124	126	128	129	130
									28.0	25.0	23.0	20.9	20.0	19.3	18.9	18.5	18.3	18.0	17.8	17.7
22	0	11	16	25	30	44	56	69	81	92	100	110	115	119	122	124	127	128	129	131
									27.2	23.9	22.0	20.0	19.1	18.5	18.0	17.7	17.3	17.2	17.1	16.8
21	0	10	15	24	29	42	55	68	81	91	100	111	116	120	123	126	128	130	131	132
									25.9	23.1	21.0	18.9	18.1	17.5	17.1	16.7	16.4	16.2	16.0	15.9
20	0	9	14	22	28	40	53	67	80	91	100	111	117	121	124	126	128	130	131	132
									25.0	22.0	20.0	18.0	17.1	16.5	16.1	15.9	15.6	15.4	15.3	15.2
19	0	9	13	22	27	39	52	66	80	91	100	111	118	121	124	126	129	130	131	132
									23.8	20.9	19.0	17.1	16.2	15.7	15.3	15.1	14.7	14.6	14.5	14.4
18	0	8	13	20	25	38	50	65	79	91	100	111	118	122	125	127	129	131	132	133
									22.8	19.8	18.0	16.2	15.3	14.8	14.4	14.2	14.0	13.7	13.6	13.5
17	0	8	12	19	24	36	48	63	78	90	100	112	118	122	125	127	129	132	133	135
									21.8	18.9	17.0	15.2	14.4	13.9	13.6	13.4	13.2	12.9	12.8	12.6
16	0	7	11	18	23	34	47	62	78	90	100	112	119	122	126	128	131	132	134	135
									20.5	17.7	16.0	14.2	13.4	13.1	12.7	12.5	12.2	12.1	11.9	11.8
15	0	6	10	17	22	33	45	61	77	90	100	113	119	123	126	129	132	133	135	136
									19.5	16.7	15.0	13.3	12.6	12.2	11.9	11.6	11.4	11.3	11.1	11.0
14	0	6	9	16	21	30	43	59	76	89	100	113	120	124	127	130	132	134	135	137
									18.4	15.7	14.0	12.4	11.7	11.3	11.0	10.8	10.6	10.4	10.4	10.2
13	0	6	9	15	20	29	41	58	75	89	100	113	120	125	128	131	133	135	136	138
									17.3	14.6	13.0	11.5	10.8	10.4	10.2	9.9	9.8	9.6	9.5	9.4
12	0	5	8	14	18	27	39	56	74	88	100	114	122	125	129	132	135	136	137	139
									16.2	13.6	12.0	10.5	9.8	9.6	9.3	9.1	8.9	8.8	8.8	8.6
11	0	4	8	13	17	25	37	55	73	88	100	114	122	126	130	133	135	137	138	140
									15.1	13.0	11.0	9.6	9.0	8.7	8.5	8.3	8.1	8.0	8.0	7.9
10	0	4	7	12	15	22	35	53	72	87	100	115	123	127	131	134	136	138	139	141
									13.9	11.5	10.0	8.7	8.1	7.9	7.6	7.5	7.4	7.2	7.2	7.1
9	0	3	6	11	14	21	31	50	70	86	100	116	124	128	132	135	137	139	141	142
									12.9	10.5	9.0	8.7	7.3	7.0	6.8	6.7	6.6	6.5	6.4	6.3
8	0	3	6	9	12	18	28	48	68	85	100	116	125	130	133	136	138	140	142	144
									11.8	9.4	8.0	6.9	6.4	6.2	6.0	5.9	5.8	5.7	5.6	5.6
7	0	3	5	7	11	16	26	46	67	84	100	117	126	131	134	137	140	142	143	145
									10.4	8.3	7.0	6.0	5.6	5.3	5.2	5.1	5.0	4.9	4.9	4.8
6	0	2	4	7	10	15	23	43	65	82	100	118	128	132	136	139	141	143	145	147
									9.2	7.3	6.0	5.1	4.7	4.5	4.4	4.3	4.3	4.2	4.1	4.1
5	0	2	3	6	7	12	20	39	62	81	100	119	129	134	[illegible]	[illegible]	[illegible]	143	147	149
									[illegible]	6.2	5.0	4.2	3.9	3.7	3.6	3.5	3.5	3.5	3.4	3.4
4	0	1	3	5	7	10	16	35	59	78	100	120	131	136	140	142	145	147	150	153
									6.8	5.1	4.0	3.3	3.1	2.9	2.9	2.8	2.8	2.7	2.7	
3	0	1	2	4	5	7	11	33	52	74	100	123	134	139	142	145	147	149	150	158
									5.7	4.1	3.0	2.4	2.2	2.2	2.1	2.1	2.0	2.0	1.9	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	5	7	27	50	70	100	[illegible]	137	143	145	148	150	160	162	165
									4.0	2.9	2.0	1.6	1.5	1.4	1.4	1.4	1.3			
1	0	1	1	2	2	3	5	15	35	50	100	130	142	150	151	155	158	172	175	177
									2.9	2.0	1.0	0.8	0.7	0.6	0.6					
0	0	0	0	0	0	0	0	0	0	0	100									

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.
**In the Extrapolated Section, values more than 100 are the Extrapolated CPrV's. Values less than 100 are the Period Converted Mean.

$$PCMDMi = \frac{100\ CMDMi}{CPrV} \text{ or } PCMDMx = \frac{100\ CMDMx}{CPrV}$$

PART VI. USE OF THE NOMOGRAPHS WITH ISOTHERMAL MAPS

The nomographs described have special significance as applied to climatic data. Let us illustrate one use, potentially world-wide, by applying it to a specific country - Germany.

1. Constructing isothermal maps of essential data

Summarized temperature data from 75 weather stations in Germany (Fig. 4) enabled us to construct 5 January isothermal maps of the country based on more than 70 50-year records:

AbMi (Fig. 5a); MDMi (Fig. 5b); MoMn (Fig. 5c);
MDMx (Fig. 5d); AbMx (Fig. 5e).

2. Predicting frequency distribution of (January) temperatures

With these maps of essential data and the appropriate nomograph, we can predict the hourly frequency distribution of January temperature for any given place in Germany.

Which 3 items of essential data we use will depend on which nomograph we intend to use. These would be:

For the General-purpose Nomograph:

AbMx MoMn AbMi

For the Alternative Nomograph:

AbMi MDMi MDMx or AbMx MDMx MDMi

For solving the present problem, the General-purpose Nomograph was selected.

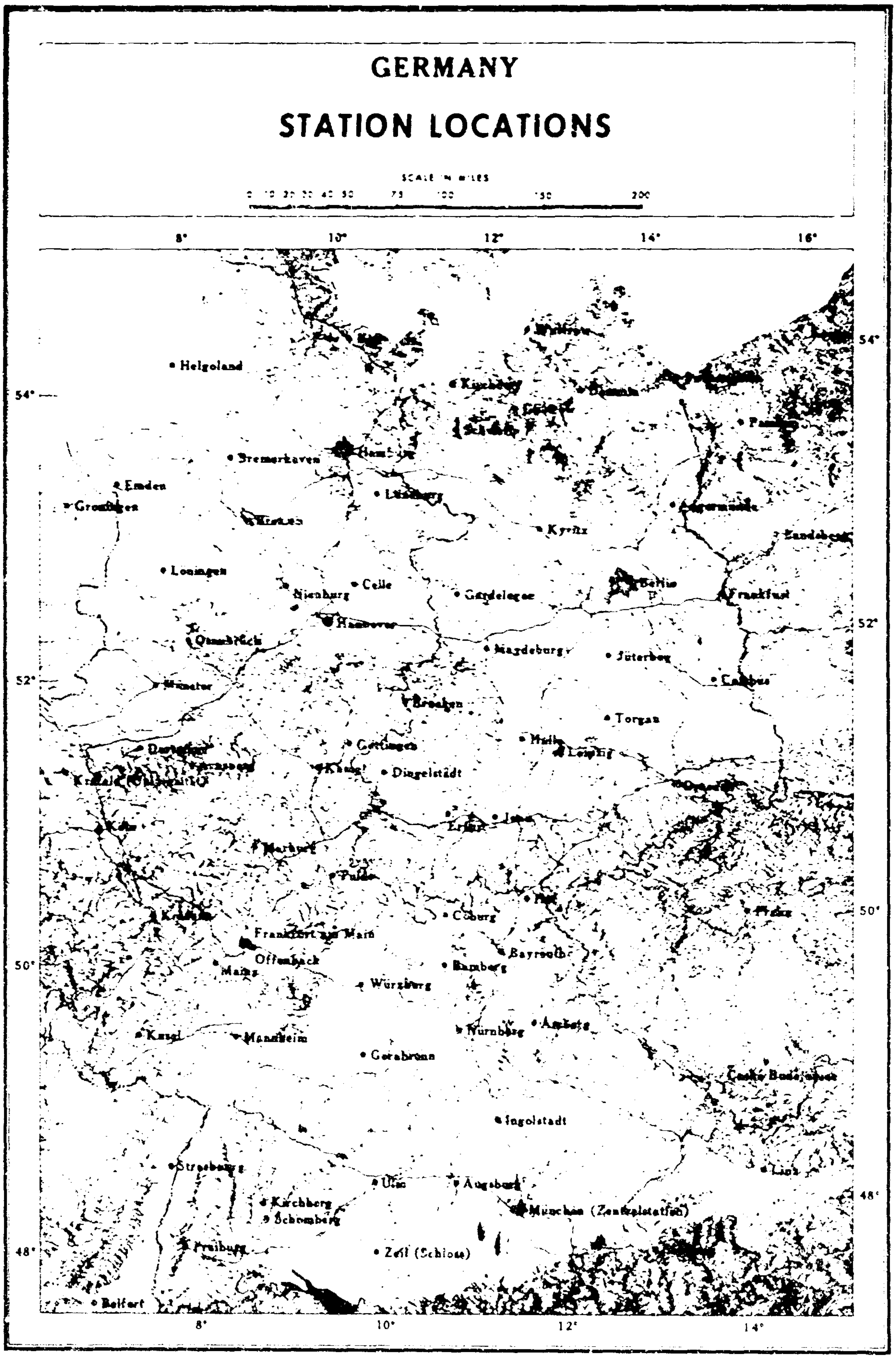
GERMANY
STATION LOCATIONS
SCALE IN MILES
Helgoland
Bremerhaven
Emden
Loningen
Celle
Nienburg
Kyritz
Gardelegen
Berlin
Frankfurt
Magdeburg
Jüterbog
Torgau
Göttingen
Dingelstädt
Halle
Leipzig
Jena
Erfurt
Marburg
Fulda
Coburg
Frankfurt am Main
Offenbach
Mainz
Würzburg
Bamberg
Bayreuth
Nürnberg
Amberg
Mannheim
Gerabronn
Ingolstadt
Ulm
Augsburg
Kirchberg
Schomberg
Freiburg
Zeil (Schloss)
Belfort
8°
10°
12°
14°
16°
48°
50°
52°
54°

Figure 4

GERMANY

JANUARY ABSOLUTE MINIMUM TEMPERATURE (AbMi) - °F.

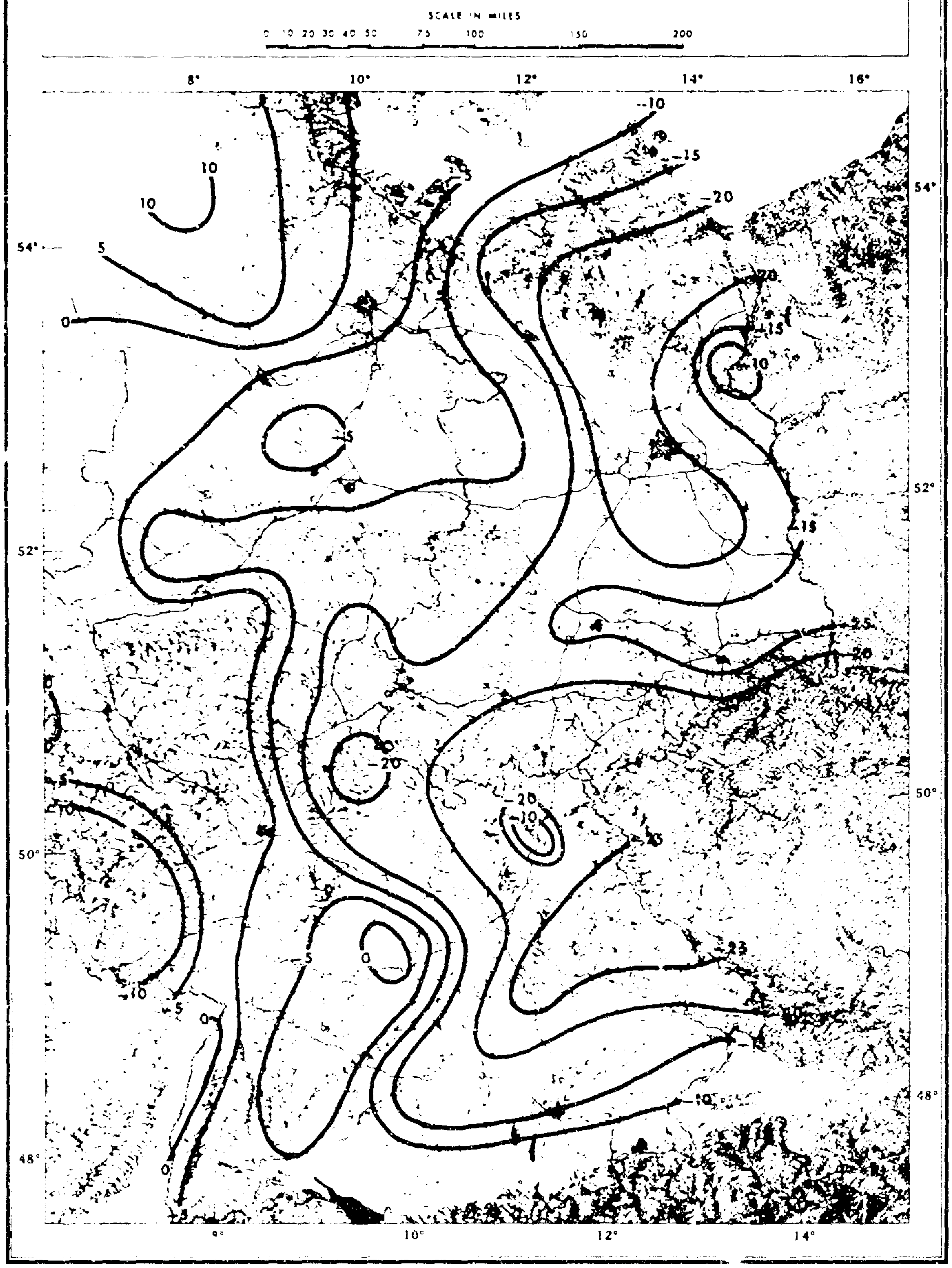

Figure 5a

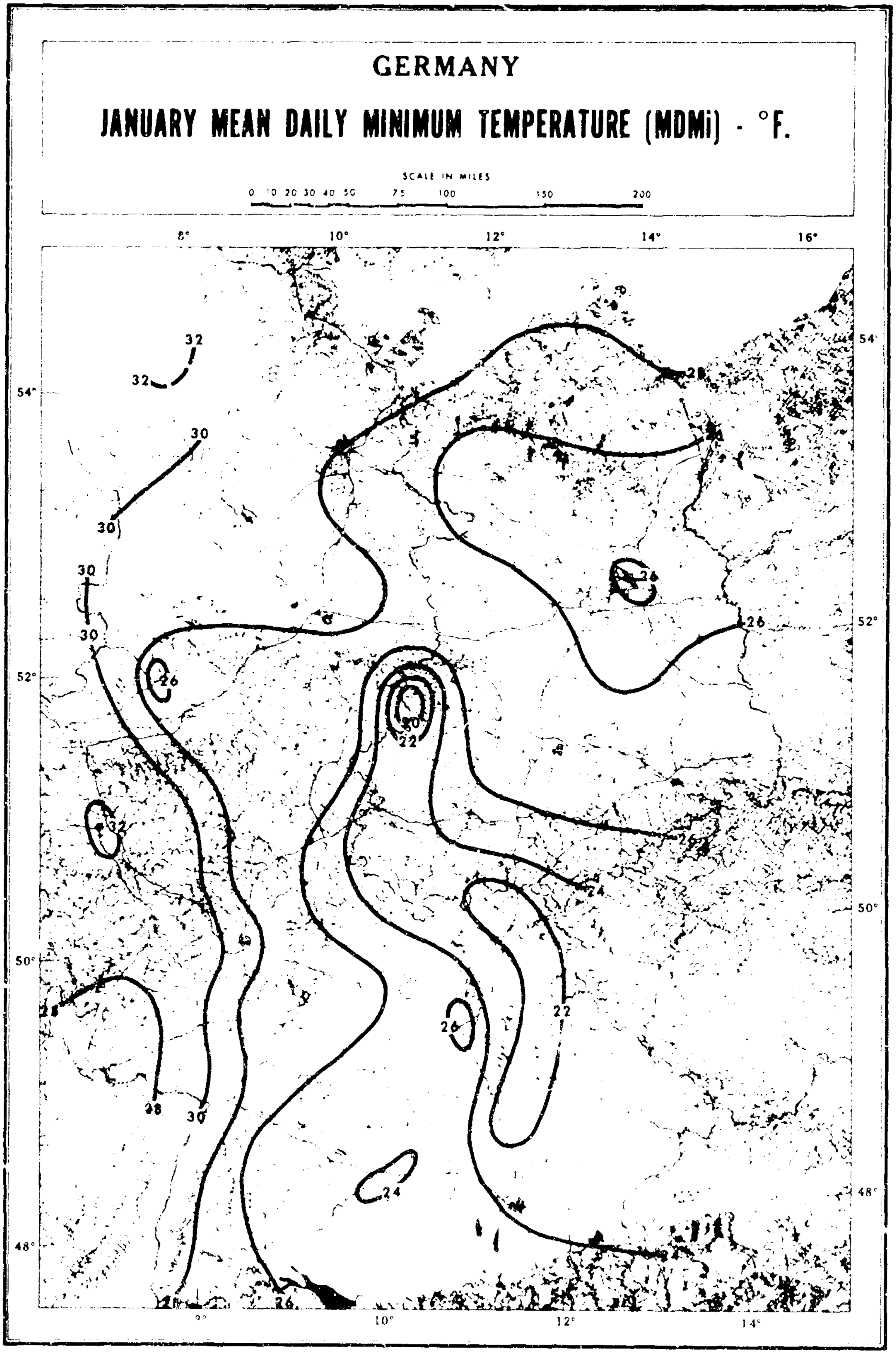
GERMANY
JANUARY MEAN DAILY MINIMUM TEMPERATURE (MDMi) - °F.
SCALE IN MILES
0 10 20 30 40 50 75 100 150 200
8° 10° 12° 14° 16°
54° 52° 50° 48°
32
30
28
26
24
22
20

Figure 5b

GERMANY

JANUARY MONTHLY MEAN TEMPERATURE (MoMn) - °F.

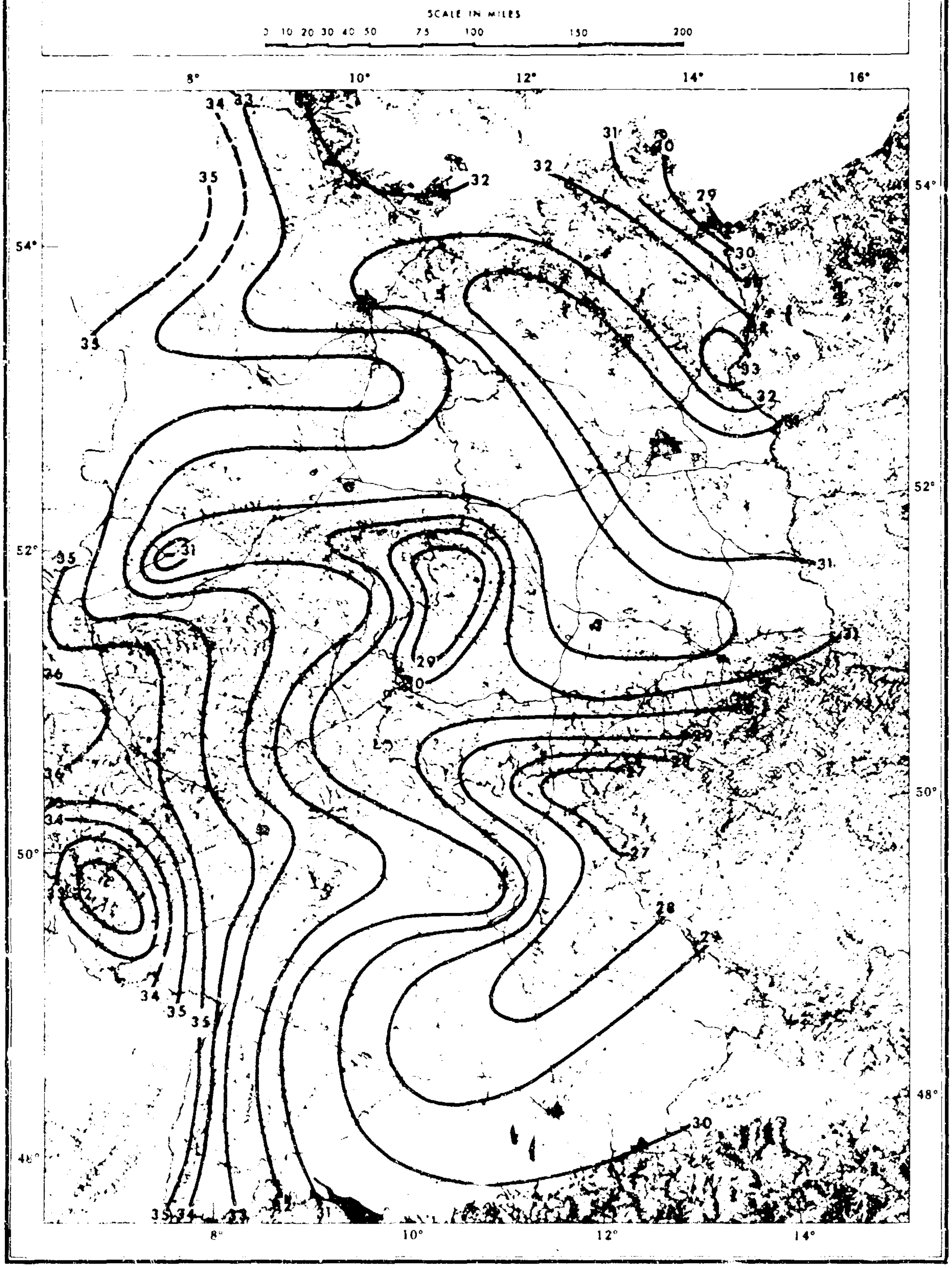

Figure 5c

GERMANY

JANUARY MEAN DAILY MAXIMUM TEMPERATURE (MDMx) - °F.

SCALE IN MILES

0 10 20 30 40 50 75 100 150 200

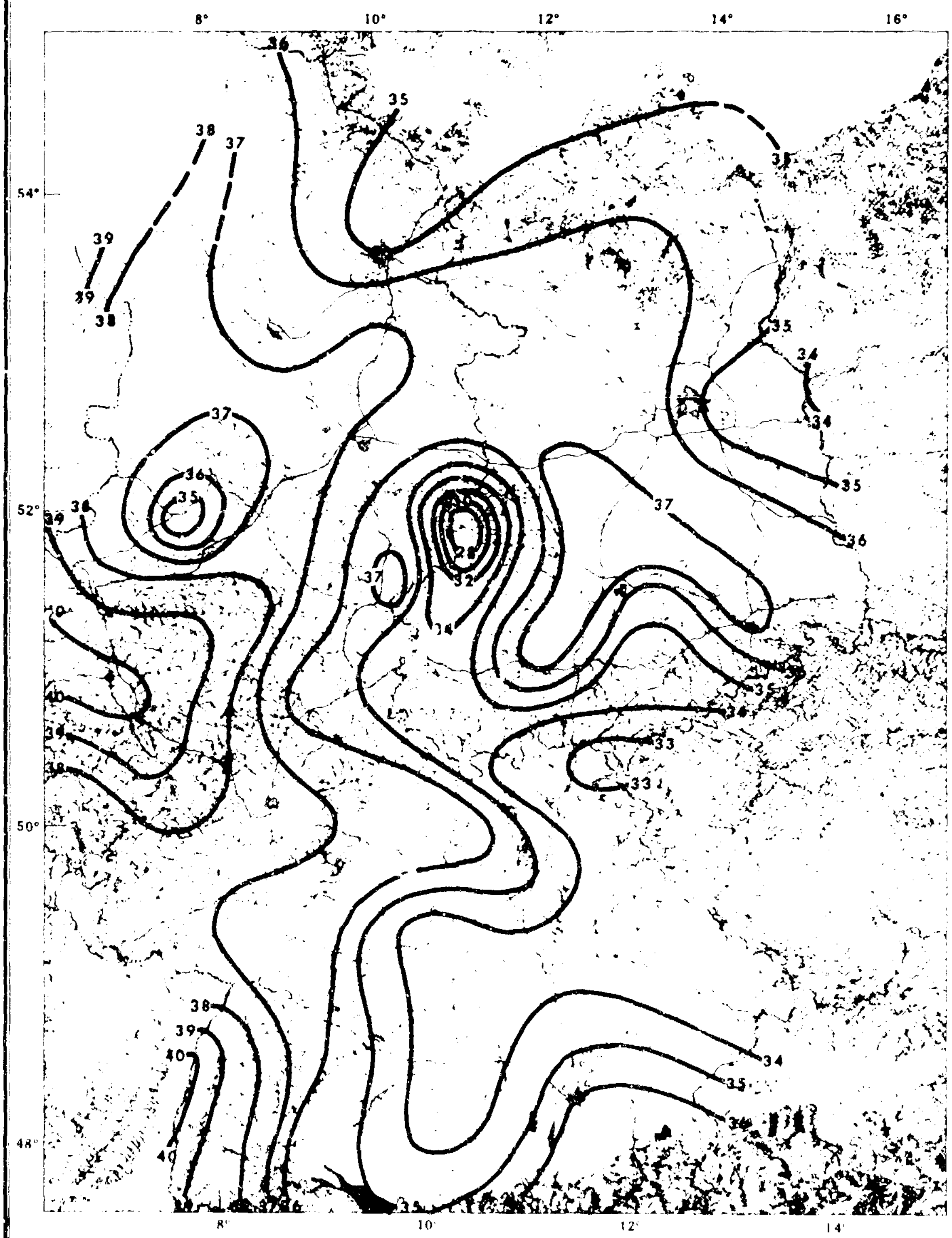

Figure 5d

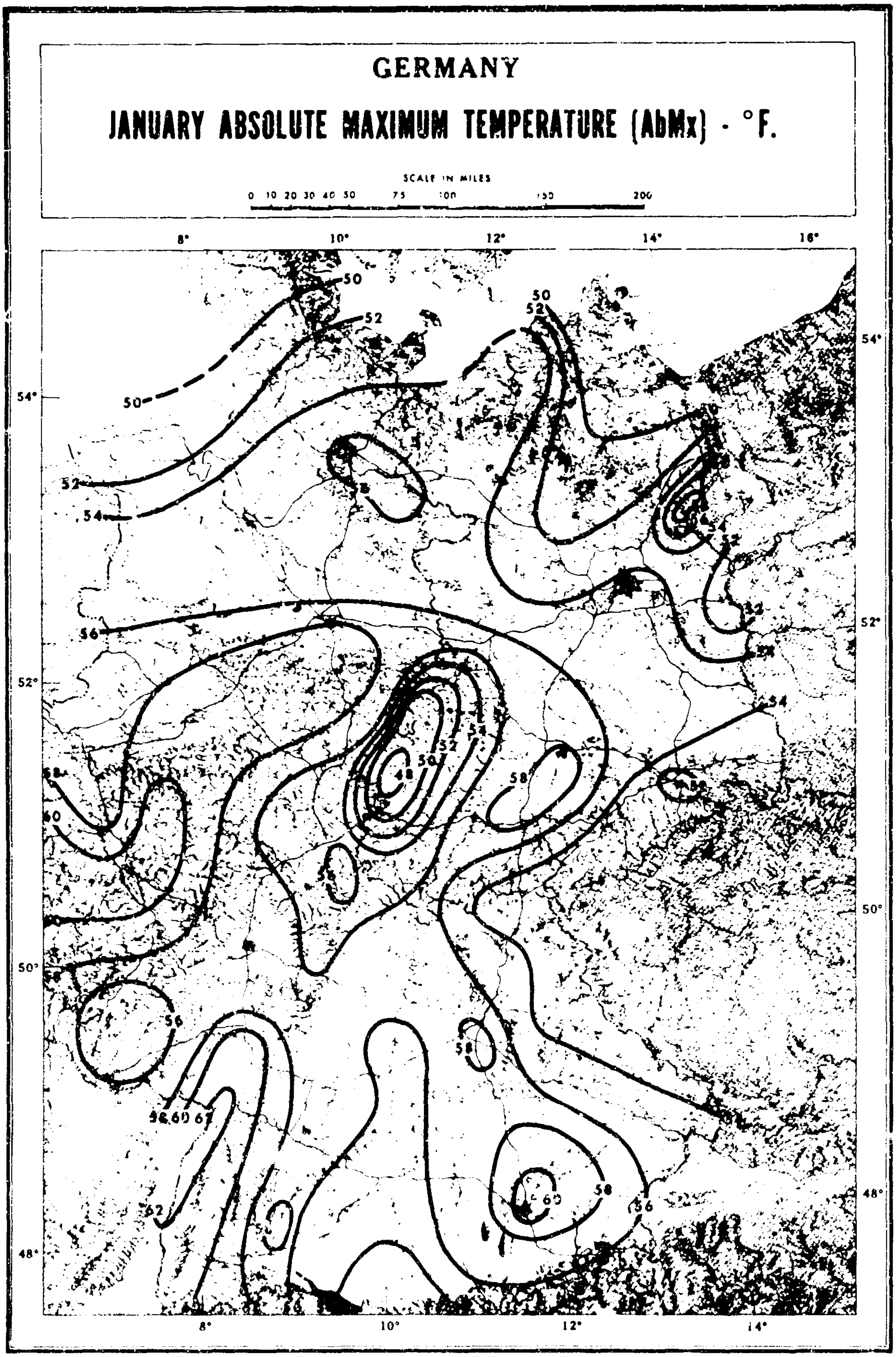
GERMANY
JANUARY ABSOLUTE MAXIMUM TEMPERATURE (AbMx) - °F.
SCALE IN MILES
0 10 20 30 40 50 75 100 150 200
8° 10° 12° 14° 16°
54° 52° 50° 48°
50
52
54
56
58
60
48
62

Figure 5e

The Stuttgart area* of Germany was a random sample to test the use of isothermal maps for predicting hourly distribution of temperature. The required essential data for the Stuttgart area are:

$$\text{AbMx} = 58°F \quad \text{MoMn} = 30°F \quad \text{AbMi} = -4°F$$

The above-listed summarized data for the Stuttgart area may be used with the General-purpose Nomograph to assess the frequency and amount of January temperatures. From the 50-year map data hourly temperature frequencies were predicted.** These are given in line F of Table V.

3. Reliability of predictions for Stuttgart area

In Table V, line D gives the observed hourly frequency record, machine-tabulated, for 5 Januaries.*** Line E gives the hourly frequencies from the 5-year summary record in line D.

It is believed that the predictions in line F, made from the 50-year map data, are just as good or better for operational purposes than the recorded hourly frequencies from the original 5-year machine-tabulated records or the predictions from the 5-year summarized records.

4. Constructing maps of temperature probabilities

Let us illustrate one use for the temperature probabilities developed from essential data by using the Nomograph. Suppose we wish to construct a January map of Germany showing the minimum temperature probabilities for 9.7% of the time, or 3 days in January. This will be done in the following steps:

a. Secure essential data

We have decided to use the Alternative Nomograph, so we will need MDMx, MDMi and AbMi. We will secure these essential data from the vertex of each degree quadrangle. For example, quadrangle A, on Figure 5d, 5b and 5a. Table VI gives the essential data so secured.

*This is an area where hourly records have been kept and tabulated which are of sufficient length to lend validity to the present nomographic method. It should be noted, especially, that the predictions are not for the Stuttgart weather station, but represent the general area in the vicinity of the relevant isotherms.

**See Appendix C for detailed steps in predicting

***Tabulated at Asheville, N.C., for Weather Corporation of America (WCA)

Table V. Machine-Tabulated January Hourly Temperature Frequencies Compared with Frequencies Predicted Manually from Summarized Records and also those predicted from Map Data. Stuttgart Vicinity in Germany.

AbMx	MoMn	AbMi	A															1/310	1/620	1/930	1/1240	1/1550	1/1860	1/2170	1/2480	1/2790	1/3100
			B	[AbMx]	1	1	1	1	1	1	1	1	1	1				10	20	30	40	50	60	70	80	90	100
			C	.323%	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%	99.5%	99.677%	99.839%	99.892%	99.919%	99.935%	99.946%	99.954%	99.960%	99.964%	99.968%
57	33	-2	D	57	51	46	43	39	37	35	34	32	31	26	19	13	11	-4									
57	33	-2	E	57	54	51	47	42	39	34	30	25	20	16	12	6	2	-4	-7	-9	-10	-11	-12	-13	-13	-14	-14
56	30	-4	F	58	54	51	46	43	39	35	30	27	22	18	15	10	6	2	0	-2	-3	-4	-5	-6	-6	-7	-7

A - Ratio probability in 31-day month(s) from 10 years (1/310) to 100 years (1/3100).
B - Number of given month involved.
C - Percentage probability for given value on a 100-unit scale from .323% (323 in 1000) to 99.968% (99,968 in 100,000).
D - Observed record, machine tabulated at Asheville, N.C., National Weather Records Center 5-year record.
E - Predicted from summary records (AbMx, MoMn and AbMi) in A. 5-year record.
F - Predicted from map data - three isothermal maps of Germany 50-year record.

Table VI: January Minimum Temperature Probabilities at 19 Different Frequency Intervals for 3 Degree Quadrangle Locations in Germany.

Quad-rangle	Location		Map Data**			Probable Frequencies of Daily Minimum Temperatures																		
						80.6%	64.5%	48.4%	32.3%	16.1%	9.7%	3.2%	1.08%	.645%	.323%	.161%	.108%	.081%	.065%	.054%	.046%	.040%	.036%	.032%
	Lat.	Long.	AbMi	MDMi	MDMx	25/31	20/31	15/31	10/31	5/31	3/31	1/31	1/93	1/155	1/310	1/620	1/930	1/1240	1/1550	1/1860	1/2170	1/2430	1/2790	1/3100
*A	51°N	07°E	-2°	31°	40°	35	33	30	28	23	19	15	11	8	5	1	0	-1	-2	-3	-4	-4	-4	-5
*B	52°N	13°E	-20°	26°	36°	31	29	25	22	16	10	4	-1	-6	-10	-14	-17	-19	-20	-21	-22	-23	-23	-24
*C	50°	11°E	-21°	24°	35°	29	27	22	20	13	6	3	-3	-8	-11	-16	-18	-20	-21	-22	-23	-24	-24	-25

*Each of these degree quadrangles (A,B,C) is marked on Fig. 4.
**The essential data needed for predicting (AbMi, MDMi, MDMx) were taken from isothermal maps Fig. 5a, 5b, 5d.

For example: At Lat. 51°N and Long. 07°E (Quadrangle A, near Köln) a minimum of 19°F may be expected at least 3 days in January or 9.7% of the time, and -2°F or lower, 1 day in 50 Januaries.

b. Compute and tabulate probable frequencies

Using the Alternative Nomograph, the probable frequencies of daily minimum temperature were computed for quadrangle A. (See Table VI.)

In the same way the data and probable frequencies were obtained for each degree quadrangle (B, C, etc.) and tabulated, as indicated on Table VI.

We are here interested in 9.7% probabilities, so we underline these in the table (Table VI). These underlined values will be used in constructing the 9.7% probability map.

c. Construct the probability map

On the map of Germany, at the various quadrangular vertices, plot the 70 or more minimum temperature values shown in the 9.7% (or 3/31) column, that is, for quadrangle A = 19; B = 10 and C = 6, etc. Draw the 9.7% isotherms through and among the plotted minimum temperature values.

This is the 9.7% map, and shows the minimum temperature to be expected at least 3 days in January in every part of Germany.

d. Wider application

Of course, corresponding maps can be drawn showing minimum temperatures to be expected for any level (80.6% to 0.032%), i.e., from 25 days in one January to 1 January day in 100 years or 100 Januaries.

The above procedures could be followed in constructing maps featuring frequency of daily maximum temperature levels (using MDMi, MDMx and AbMx data).

Similar procedures could be used for rainfall, or other climatic data. Or the procedures could be adapted to use of the General-purpose Nomograph and its appropriate essential data (AbMx, DMn, AbMi).

This procedure is applicable for any part of the world where essential summarized climatology data are available.

It is believed that the temperature data derived from such maps is sufficiently reliable to fall well within the calculated risks of military expediency, and may be used with confidence at least until better criteria are found and evaluated.

Summary

A. The value, use and construction of the 100-unit nomographs presented in this study are based on the assumption that the frequency distributions of measures of given phenomena differ from the normal according to patterns which are more or less inherent in their summary measures. The construction of the two nomographs depends largely on which values in the summaries are utilized as parameters in their make-up.

In Figure 1 and Table I, the 101 converted mean patterns (CMn), each with its unique series of converted predictive values (CPrV), depend for their utility entirely on four (4) parametric values. These summary measures are:

AbMx	-	Absolute Maximum
AbMi	-	Absolute Minimum
Mn	-	Mean or Average
	-	Length of Record

Given these 4 parametric measures, commonly available in summarized climatic records, the approximate details of a climatic record may be retrieved.

B. Some categories of summarized data include the average or mean of a series of extremes, i.e., the mean maximum (MMx) and mean minimum (MMi). In this case, these two parametric values together with the extremes may be used in the construction of the Alternative Predictive Nomograph (Figure 3).

Theoretically, the prediction from the two nomographs should agree (approximately) when applied to a given summary record. The anchor position (CMn = 0 and CMn = 100) from which all probabilities (CPrV's) are measured in Figure 1 is either the absolute maximum or absolute minimum; this is not as stable as the anchor position of mean maximum (MMx) or mean minimum (MMi) as in Figure 3.

C. The author believes that these two nomographs are fairly good instruments, but should be considered tentative, and should be subjected to rigorous tests and subsequent revision. Therefore, this investigator invites and welcomes suggestions for the revision or modification of these two prognostic instruments.

REFERENCES

1. Brackenseik, Fitting a generalized log-normal distribution to hydrologic data, J Geophys Research, 39: 469-473 (1958)

2. Croxton, F. E. and Cowden, D. J., Practical business statistics, pp 204-207, Prentice Hall In , New York N Y, 1937

3. Garrett, Henry E., Statistics in psychology and education, p 3, Longmans, Green and Co, New York, N Y, 1936

4. Gumbel, E. J. and Julius Lieblein, Some applications of extreme value methods, Amer Statistician, Vol 8, No 4, 1954

5. Lackey, Earl E., A method for assessing hourly temperature probabilities from limited weather records, Bull Amer Meteorol Soc, 41:298-303, June 1960

6. -----, Assessing daily minimum temperature probabilities from abbreviated weather records, Prof Geog, 12: No 5, 1-7

7. -----, A method for assessing the frequency and amount of 1-day rainfall, Tech Rpt ES-9, U.S. Army Natick Laboratories, Natick, Mass, June 1964

8. -----, A method for assessing daily maximum temperatures from summarized weather records, Tech Rpt ES-13, U.S. Army Natick Laboratories, Natick, Mass, Aug 1964

9. -----, A method for predicting the probable frequency of daily minimum temperatures from summarized data, Tech Rpt ES-18, U.S. Army Natick Laboratories, Natick, Mass, Dec 1965

10. Quartermaster Research & Development Center, Natick, Mass: Environmental Handbooks -

    Handbook of Fort Churchill, Manitoba, Canada environment (de Percin & White), Tech Rpt EP-4, Aug 1954

    Handbook of Devils Lake, North Dakota, environment (de Percin and Bingham), Tech Rpt EP-8, Apr 1955

    Environmental Handbook of Fort Sherman and Fort Gulick, Panama Canal Zone, (Wiley, Dodd and Chambers), Tech Rpt EP-17, July 1955

11. Spreen, William C., Empirically determined distributions of hourly temperatures, J Meteorol, Vol. 13, No. 4, pp. 381-385, Aug 1956

12. U.S. Weather Bureau, Maximum station precipitation for 1, 2, 3, 6, 12, and 24 hours, Parts I to XXVI, Tech Paper 15, Washington, D.C., 1951-61

APPENDIX A

ABBREVIATIONS

AbMx = Absolute Maximum
The highest measure recorded in a given series of observations of a climatic or other variable.

AbMi = Absolute Minimum
The lowest measure recorded in a given series of observations of a climatic or other variable.

Mn = Mean
The sum of a series of measures divided by the number of measures, to give the average value.

DMn = Daily Mean
The average of a given series of daily measures.

MoMn = Monthly Mean
The mean of a series of monthly averages for a given month in each year of record.

MDMx = Mean Daily Maximum
The average of the daily maxima (in this study, for a given month only in each year) during the period of record.

MDMi = Mean Daily Minimum
The average of the daily minima (in this study, for a given month only in each year) during the period of record.

CAbMx = Converted Absolute Maximum
The AbMx changed to 100 on the 100-unit scale.

CAbMi = Converted Absolute Minimum
The AbMi changed to 0 on the 100-unit scale.

CMn = Converted Mean
The mean occupying the same relative position between extremes as in unconverted observations, but expressed as a value on the 100-unit scale between 0 (CAbMi) and 100 (CAbMx).

CMDMi = Converted Mean Daily Minimum
Average of the reduced daily minima converted to the 100-unit scale as in Table IV.

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CMDMx = <u>Converted Mean Daily Maximum</u>
Average of the reduced daily maxima converted to the 100-unit scale as in Table IV.

CPrV = <u>Converted Predictive Values</u>
The cumulative frequency predictive values associated with each of the 101 CMn's (left margin Table I and Table IV), e.g., CPrV's on line CMn 60.

PCMn = <u>Period Converted Mean</u>
See footnote Table I and Table IV.

APPENDIX B

PROBLEM SOLUTION: ASSESSING FREQUENCY AND PROBABLE AMOUNT OF 1-DAY RAINFALL, USING GENERAL-PURPOSE NOMOGRAPH

In this type of problem, we are given the 10-year record and use the Extrapolated section of the Nomograph or its associated Table to predict for decades beyond 10 years. The specific subject, April rainfall in New Orleans, was previously discussed (see Table I, ref. 7), but in the following problem the present Nomograph (Fig. 1) was used.

1. <u>Statement of problem</u>

<u>Given</u>: At New Orleans during a 10-April period (300 April days in 10 years) the monthly mean (MoMn) rainfall was 4.94" and the 1-day maximum (1-day Mx) was 5.8".

<u>Required</u>: What is the probable 1-day maximum April rainfall to be expected in 20 years? 50 years? 100 years?

2. <u>Solution of problem</u>

a. <u>Find the CMn (1-day converted mean)</u>

<u>Formula</u>:

$$\text{1-day CMn} = \frac{100\ (\text{MoMn})}{30\ (\text{10 April 1-day Mx})}$$

(Substituting)

$$= \frac{100\ (4.94)}{30\ (5.89)} = 2.81 \text{ or } 3$$

Therefore, 1-day <u>CMn 3</u> pattern of CPrV is to be used for predictions.

b. <u>Find the CPrV's</u>

On the General-purpose Nomograph, follow along CMn 3 from the left margin to its intersection with the 20-year curve, thence upward to <u>124</u>; to the intersection with the 50-year curve, thence upward to <u>146</u>; and for the 100-year curve, thence upward to <u>168</u>. These are the converted predictive April 1-day rainfalls. These CPrV's are more easily found on the equivalent table. Using the CMn pattern of 3 in Table I, follow along from the left margin until under column head for 20 years: <u>124</u>; for 50 years: <u>146</u>; and for 100 years: <u>168</u>.

c. <u>Reconvert to conventional measures</u> (inches)

<u>Formula</u>:

$$\text{1-day maximum} = \frac{(10\ \text{April 1-day Mx})\ (\text{CPrV})}{100}$$

$$\text{20 April 1-day Max} = \frac{5.89''\ (124)}{100} = 7.30''\ \text{at least}$$

$$\text{50 April 1-day Mx} = \frac{5.89''\ (146)}{100} = 8.60''\ \text{at least}$$

$$\text{100 April 1-day Mx} = \frac{5.89''\ (168)}{100} = 9.90''\ \text{at least}$$

APPENDIX C

PROBLEM SOLUTION: ASSESSING TEMPERATURE FREQUENCIES, BASED ON 50-YEAR SUMMARY RECORDS, USING GENERAL-PURPOSE NOMOGRAPH

This is a step-by-step solution of the problem discussed in VI,2 of this report, with results given in Table V, line F.

1. Statement of problem

Given: The following essential data from isothermal maps, Figs. 5 e,c,a

AbMx = 58°F MoMn = 30°F AbMi = -4°F

Required: To assess the percentage frequency of January daily temperatures, based on 50-year summary map records, for the vicinity of Stuttgart, Germany.

2. Solution of problem

a. Reduce the 3 items by subtracting each from AbMx, so that:

AbMx = 0 MoMn = 28 AbMi = 62

The 50-year range is 62F°.

b. Find the 50-year CMn

Formula:

$$\text{PCMn} = \frac{100\ (\text{MoMn})}{\text{Range}}$$

(Substituting)

$$= \frac{100\ (28)}{62} = 45.2$$

PCMn 45.2 is for a 50-yr period record.

c. Find the 10-year CMn pattern equivalent to PCMn 45.2

In Table I, follow down the 50-yr column series of PCMn's (figures less than 100) to the one nearest 45.2. This is 45.5 and is found associated in the 10-yr table (follow line to left margin) with the CMn 50 pattern of CPrV's.

The 10-yr CMn 50 pattern will serve for prediction purposes.

d. <u>Find the required CPrV's</u>

On Table I, on the CMn 50 line, find the required CPrV under the appropriate column heading, e.g., 30-yr CPrV = 107; 50-yr CPrV = 110; 100-yr CPrV = 115.

e. <u>Find what the 10-year range would be, corresponding to 50-yr range (62°F)</u>

<u>Formula</u>:

$$\text{10-yr range} = \frac{100\ (\text{50-yr range})}{\text{50-yr CPrV}}$$

(Substituting)

$$= \frac{100\ (62)}{110} = 56.4$$

f. <u>Find required percentage frequency temperatures</u>

<u>Formula</u>:

$$\text{Percentage frequency temp.} = \text{50-yr AbMx} - \frac{\text{10-yr range* (CPrV's**)}}{100}$$

(Substituting)

$$\text{For 1 day in 30 years} = 58 - \frac{56.4\ (107)}{100} = -2$$

$$\text{For 1 day in 100 years} = 58 - \frac{56.4\ (115)}{100} = -7$$

These and other frequencies are given in Table V.

*As in step e above.
**As in step d above.

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U.S. Army Natick Laboratories	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

3. REPORT TITLE

A GENERAL NOMOGRAPH FOR NORMAL AND SKEWED FREQUENCY DISTRIBUTIONS: CLIMATOLOGICAL AND OTHER APPLICATIONS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

LACKEY, EARL E.

6. REPORT DATE July 1967	7a. TOTAL NO. OF PAGES 44	7b. NO. OF REFS 12
8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) 68-40-ES	
b. PROJECT NO. 1T025001A129		
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ES-26	
d.		

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Earth Sciences Laboratory, U.S. Army Natick Laboratories, Natick, Mass.

13. ABSTRACT Extended experience in the construction and use of several different predictive nomographs covering a wide range of frequency distributions of various types of weather and other phenomena, suggested the probability that a universal series of patterns of frequency distributions might permeate the whole of nature. This study is based in part on the several nomographic patterns developed in previous studies. It assumes that all of the frequency distributions we are likely to encounter in practical climatology, whether symmetrical or asymmetrical (skewed), may be fairly well approximated by a family of cumulative frequency curves, provided they are plotted on such a scale that 100 units represents the whole range of observational experience in each.

The predictive patterns in the General Nomograph and its associated table depend for their operation on the numerical position of the mean (average) between the two extremes (maximum and minimum) in the frequency distribution, when the three related measures are reduced to a 100-unit scale. The means of frequency distributions having various degrees of skewness lie along a diagonal line from the lower left to the upper right of the basic section of the nomograph. Other lines (curved) trace the values of other percentile or fractional parts of the various distributions. The construction, use and reliability of this nomograph and its associated table are given in this report.

Similar predictive patterns in an Alternative Nomograph and its associated table are identified by the numerical position of: (1) the mean maximum between the absolute maximum and the mean minimum, or (2) the mean minimum between the

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13. ABSTRACT (Continued)

absolute minimum and the mean maximum, depending on which extreme is being explored. A 100-unit scale based on the above values is used in each case. The Alternative Nomograph thus illustrates the possibility of using parametric data other than means and extremes as the basis for a nomograph, if that should be necessary, or should prove to be a better basis for frequency prediction.

The essential summarized data for use with either nomograph may be secured from printed publications or from isothermal maps. How each source of summarized data may be used, for retrieval or predictive purposes, is shown and the results are verified by comparison with recorded data in the same vicinity.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Design	8					
Nomographs	9,2		10			
Skewed distributions	1					
Normal distributions	1					
Parameters	1					
Prediction	4		8			
Probability	4					
Climatology	4					
Industrial psychology	4					
Psychometrics	4					
Weather conditions			9			